Independent Assessment of NASA Expendable Launch Vehicle Safety & Mission Assurance Processes

NASA Headquarters
Office of Safety & Mission Assurance
August 30, 1999

Executive Summary

Introduction

The NASA Expendable Launch Vehicle (ELV) program officially moved to Kennedy Space Center (KSC) on October 1, 1998. The move consolidated engineering and management functions previously performed at Glenn Research Center (GRC) and Goddard Space Flight Center (GSFC) over the past 30 years.

The ELV program office at KSC is staffed by a dedicated, committed, and hardworking group of professionals, including a small, but excellent, cadre of experienced ELV engineers recruited from GSFC and GRC. Integrating the three engineering cultural norms to obtain the "best of the best" is a good approach. However, the transition remains a work in progress. The review team recognizes many ELV Program strengths. These strengths include the Mission Integration Team approach, the Engineering Review Board, the mission analysis and independent verification and validation capability, the presence of engineering representatives in ELV manufacturing facilities, and an aggressive, assurance-minded ELV procurement group. Equally dedicated and professional staff in the Safety and Mission Assurance (SMA) office are working hard to build an ELV assurance organization that can provide a strong independent assurance capability. SMA is building on a small group of experienced field-based flight assurance managers and a nucleus of experienced ELV quality assurance technicians.

Maintaining ELV Mission Success

NASA's success rate for the last 47 ELV launch attempts has been excellent. However, this record reflects, to a large extent, the success of past GSFC and GRC ELV management experience and practice. While eight of the last launch attempts have occurred since the official transition of program management to KSC, the success of these recent missions cannot be viewed as validation or certification of KSC ELV assurance processes (an ELV mission typically takes 30 months from initiation to launch). The KSC ELV organization is a new team with an evolving management structure and approach. There is no cause for complacency. Effective implementation of ELV assurance processes (especially in a new organization) depends on clear policies, clearly defined management expectations for mission success, documented processes, and, in particular, resources that match the scope of responsibilities.

<u>Office of Safety and Mission Assurance</u>

Continued success will depend on NASA management moving with deliberate purpose to address current ELV management issues. The Headquarters Office of Safety and Mission Assurance (OSMA) must start this process by developing a top level ELV assurance requirement document and then perform SMA functional audits necessary to assure that a robust ELV assurance capability is indeed implemented at KSC.

Office of Space Flight

The Office of Space Flight (OSF) must move to clarify ambiguities regarding depth and breadth of insight activities for core vehicle hardware and software and the mission-to-mission implementation of independent analysis assurance activities.

NASA's past success rate was built upon a foundation of workforce stability and experience including vehicle design, development, test, and operation. The GSFC and GRC ELV workforce understood how to interpret the requirements of NASA Management Instruction (NMI) 8610.23. The KSC ELV Program is still evolving and developing as an organization and needs assistance in interpreting the high level guidance of NMI 8610.23, while balancing an increased workload and management expectations for mission success. OSF must also realistically assess the resource requirements necessary to operate a viable, consolidated ELV Program office (with the supporting SMA organization) and most importantly, must provide the funding and staffing necessary for implementation. Finally, OSF must work with OSMA, the Chief Engineer, and ELV customers to establish an ELV mission risk acceptance policy.

NASA Chief Engineer

The review team noted a universal sense among those interviewed that NASA Headquarters has an expectation for 100% mission success. With limited resources and increasing workload all missions simply cannot be afforded the same attention. Payloads vary from relatively simple secondaries to large complex observatories and allocation of resources should be commensurate with the overall mission value. A clear need exists to establish general assurance-level categories to guide ELV and SMA personnel. It is recommended that the NASA Chief Engineer assist in defining the depth of core vehicle insight and the extent of independent analysis activities for each mission by establishing an ELV risk management forum. The forum could function in connection with the Flight Assignment Board and use an approach similar to that employed in NASA Policy Directive (NPD) 8610.7, "Procurement Risk Strategy."

Kennedy Space Center

KSC management has issues to address as well; clarifying ELV assurance roles and responsibilities, flowing down Headquarters policies into Kennedy Documented Processes (KDP's), and assuring that resources are allocated (staffing and contractor dollars) to implement viable ELV Program and supporting SMA organizations. The ELV Program office must move aggressively to identify and document critical engineering and assurance processes. The ELV Program must also define resource needs, and working with OSF, move to fill vacancies in critical skill areas.

The KSC SMA organization must move to accept (and embrace) the overall ELV assurance responsibility. An integrated ELV assurance implementation plan must be developed and resources must be allocated to assure a reinforced flight assurance presence in manufacturing facilities with the intent of verifying, on an ongoing basis, that critical contractor assurance processes are implemented. Finally the SMA participation in ELV Certificate of Flight Readiness processes must be formally documented and supported by demonstrated knowledge and understanding of assurance process implementation.

ELV Failure Gap Analysis

The team examined 25 ELV failure case studies to subjectively assess whether or not NASA KSC in-place assurance processes would have prevented the mishap from occurring.

It should be noted that the review team fully appreciates the very subjective nature of the assessments made herein. In fact, one of the purposes of conducting this gap analysis was to stimulate thinking and discussion regarding the adequacy of current ELV mission assurance processes. Hence, the review team invites the ELV program management at Headquarters and KSC to undertake their own analysis as a means to gain further insight and understanding of current mission assurance processes and to quickly focus on areas requiring improvement.

Finding

The review team does not believe the current level of NASA core vehicle insight will detect subtle errors in contractor execution of critical processes. Nor does the team believe that latent core vehicle design defects existing within "proven" launch systems would be detected. However, increasing the breadth of NASA assurance coverage and the depth of that coverage would improve NASA's posture for detecting mission critical flaws.

Opportunities Exist to Maintain Excellent Success Rate

NASA ELV launch service contracts are structured to provide NASA the opportunity to detect potential failure modes in design analysis, design verification and verification testing areas. However, in order for the KSC ELV organization to seize upon the contractually provided failure mitigation opportunities the workforce must be provided with:

- clear policy guidance (how deep and how wide) (recommendations P1, P3),
- clarification of roles and responsibilities, (recommendation R2),
- clear mission specific assurance expectations, (recommendation P2), and
- necessary staffing, and contractor support, (recommendation R1).

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1.0 Introduction

1.1 Independent Assessment Background and Methodology

In response to a recent series of expendable launch vehicle (ELV) failures (August 1998 to May 1999), the Office of Safety and Mission Assurance (OSMA) initiated an independent assessment to identify and evaluate processes employed by NASA ELV program management and the NASA safety and mission assurance (SMA) community to assure safety, manage risk, and maximize the likelihood of mission success.

Although there are a number of private industry and government reviews currently underway, including the U.S. Air Force Broad Area Review, considerable NASA management concern exists regarding the breadth and depth of NASA ELV assurance processes and the potential vulnerability of upcoming launches. These concerns reinforced the need to move forward with an independent assessment.

Going into space or flying at hypersonic speeds at the edge of space are difficult and serious endeavors - follow the rules or suffer the consequences. One must follow the rules of complete, thorough, time-tested systems engineering and program management discipline. Cutting corners will expose the program to risks greater than those already inherent in aerospace programs. The most reliable launch system to date, the Space Shuttle, has experienced an approximate one percent failure rate. ELV's as a group have historically failed approximately five percent of the time. NASA obviously wants and needs to drive space flight failure probabilities down as far as possible to protect the public, protect the lives of our astronauts and employees, and to help our one-of-a-kind payloads reach their destinations.

In the commercial communication satellite business, the inherent risk in achieving orbit is mitigated through purchasing insurance. Purchase of insurance is one form of risk mitigation employed by commercial vendors. Some choose to self insure, others build extra spacecraft. This model works for the private sector. However, conventional insurance does not provide similar satisfaction or protection when NASA loses a high-value scientific payload or a human life. NASA's best and only insurance must be enhanced assurance.

1.1.1 OSMA Independent Assessment Objectives

OSMA's independent assessment had three primary objectives:

- Identify management, contract monitoring, configuration control, systems engineering, manufacturing production, testing, vehicle integration, and pre-launch operational processes established and currently implemented by the NASA ELV Program and SMA organizations to assure safety and maximize the likelihood of launch vehicle/payload mission success.

- Evaluate process implementation and recommend means to strengthen the overall government/industry assurance approach.
- Analyze recent launch failures, mapping probable causes to potentially mitigating assurance processes that may or may not currently be implemented by NASA or commercial launch vehicle providers.

1.1.2 Scope

The Process Readiness Review (PRR) approach was used to evaluate assurance processes and activities implemented by:

- NASA Headquarters ELV Program Office
- NASA Headquarters OSMA
- NASA Kennedy Space Center (KSC) ELV Program Office (including processes supported by elements of the Goddard Space Flight Center (GSFC), Glenn Research Center (GRC), and Marshall Space Flight Center (MSFC))
- NASA KSC SMA

In general, the PRR approach or methodology is implemented through a series of phases: 1) Kickoff; 2) Discovery; 3) Data Synthesis and Evaluation; 4) Draft Report Preparation; and 5) Final Report Preparation. Further details regarding each of these phases are provided in the following paragraphs.

<u>Kickoff</u>

A kickoff letter is prepared which formally initiates the independent assessment. Its purpose is to identify the principle organizations involved, define their roles and responsibilities, and to establish the scope and objectives of the assessment. The letter to initiate OSMA's independent assessment of the ELV Program was sent to the Office of Space Flight on May 12, 1999.

<u>Discovery</u>

The Discovery phase begins with the identification, collection, and review of all pertinent documentation. This typically includes all relevant NASA policy documents (NPD's/ NPG's) and standards. In regard to this particular independent assessment, those documents pertinent to ELV program management, such as KSC's Business Objectives and Agreements (BOA's), SMA Annual Operating Agreements (AOA), Kennedy Documented Procedures (KDP's), current Memorandums of Understanding (MOU's), and existing ELV contracts were assembled and reviewed. A complete listing of all documents for this assessment is found in appendix B.

The next steps in the Discovery phase involve the conduct of individual interviews with the principal assurance process owners. This is usually accomplished by holding an initial series of telecons that are then followed by onsite visits. These represent the principal mechanisms by which objective evidence is obtained to verify process fidelity and implementation. For this particular assessment telecons were conducted during the weeks of June 28 and July 5, 1999, and the onsite visit to KSC was completed on July 12-14, 1999. A complete list of all telecons and onsite visits, identifying the principal individuals and their programmatic affiliation, is contained in appendix C. Appendix D provides the question set used during the conduct of the interviews.

It should be noted that the initial stages of this ELV assessment included the collection and evaluation of specific mission assurance data and documentation necessary to support Certification of Flight Readiness (CoFR) for the QuickSCAT/Titan II and FUSE/Delta II missions. A listing of this information is included in appendices B and C.

<u>Data Synthesis and Evaluation</u>

Based on the information obtained during the Discovery phase of this assessment, i.e., review of pertinent ELV documentation, telecon, and onsite interviews with assurance process owners, the review team developed an ELV Assurance Process Map. The purpose of this map was to capture in a single organizational/functional flow diagram the totality of the mission assurance activities, key participants, and principal interfaces which are in place to assure safety, manage risk, and maximize the likelihood of mission success. A detailed description of this process map is provided in section 2.0 of this report.

<u>Draft and Final Report Preparation</u>

Typically, two sets of draft reports are prepared. The first, which is referred to as the factual review draft, represents those sections of the report that present the body of factual or objective evidence compiled by the review team. This draft is submitted to the to the organization under review and to those individuals who were interviewed during the telecons and onsite visits for review and validation. The second draft combines the factual review draft with the review team's findings, conclusions, and recommendations. This is submitted for an internal review and evaluation. Final report preparation follows. As related to this assessment, the factual and internal reviews were completed by August 20, 1999, and the final report was delivered August 30, 1999.

1.1.3 OSMA Independent Assessment Core Team

- J. Steven Newman (Independent Assessment Team Lead)
- Stephen M. Wander (Independent Assessment Team)
- Claude Smith (Independent Assessment Team)
- Phil Napala (Payloads Mission Assurance)
- Roger Mielec (Expendable Launch Vehicle Mission Assurance)
- John Castellano (former ELV Large and Intermediate Launch Vehicle Branch Chief)

The review team received excellent support from Ms. Robyn Witter of the KSC/SMA/ELV organization who provided management and logistics assistance to the team. Ms. Witter also served as the KSC report production coordinator. The team also appreciates the support of Mr. Raymond Lugo, Mr. Michael Benik and the many members of their staff that supported the review.

1.1.4 Methodology

OSMA has developed the Process Based Mission Assurance (PBMA) model as the basic framework against which the capability and fidelity of NASA ELV program and supporting SMA processes are examined and evaluated. The model, described below and depicted in figure 1.1, represents the best of current industry and government practices for assuring safety, managing risks, and maximizing the likelihood of mission success. The PBMA model provided the basis for determining X-33 and X-34 program eligibility for third-party indemnification as required under the Space Act of 1998. It has also been used to evaluate the capability and stability of Space Shuttle Ground Operation processes employed by United Space Alliance (USA) at KSC. Detailed NASA ELV assurance process profiles are provided in appendix A of this document.

1.1.5 The PBMA Model

The PBMA model or framework consists of the ten basic assurance process elements depicted in the graphic below. The PBMA elements parallel a typical project design and development cycle reflecting the importance of a systems engineering or life cycle assurance approach. Risk management serves as a philosophy and a mental discipline as well as a formal tool within the PBMA model. The backbone of the PBMA approach is a risk management philosophy and the recurrent use of the risk management discipline. This includes: 1) identification and analysis of risk, i.e., failure modes, hazards, sources of variation, etc.; 2) planning for control and mitigation of potential failure mechanisms; and 3) documentation, review, and tracking of identified risks. Program management consensus and informed acceptance of residual risks are crucial elements of informed management decision making.

Assurance Model Elements

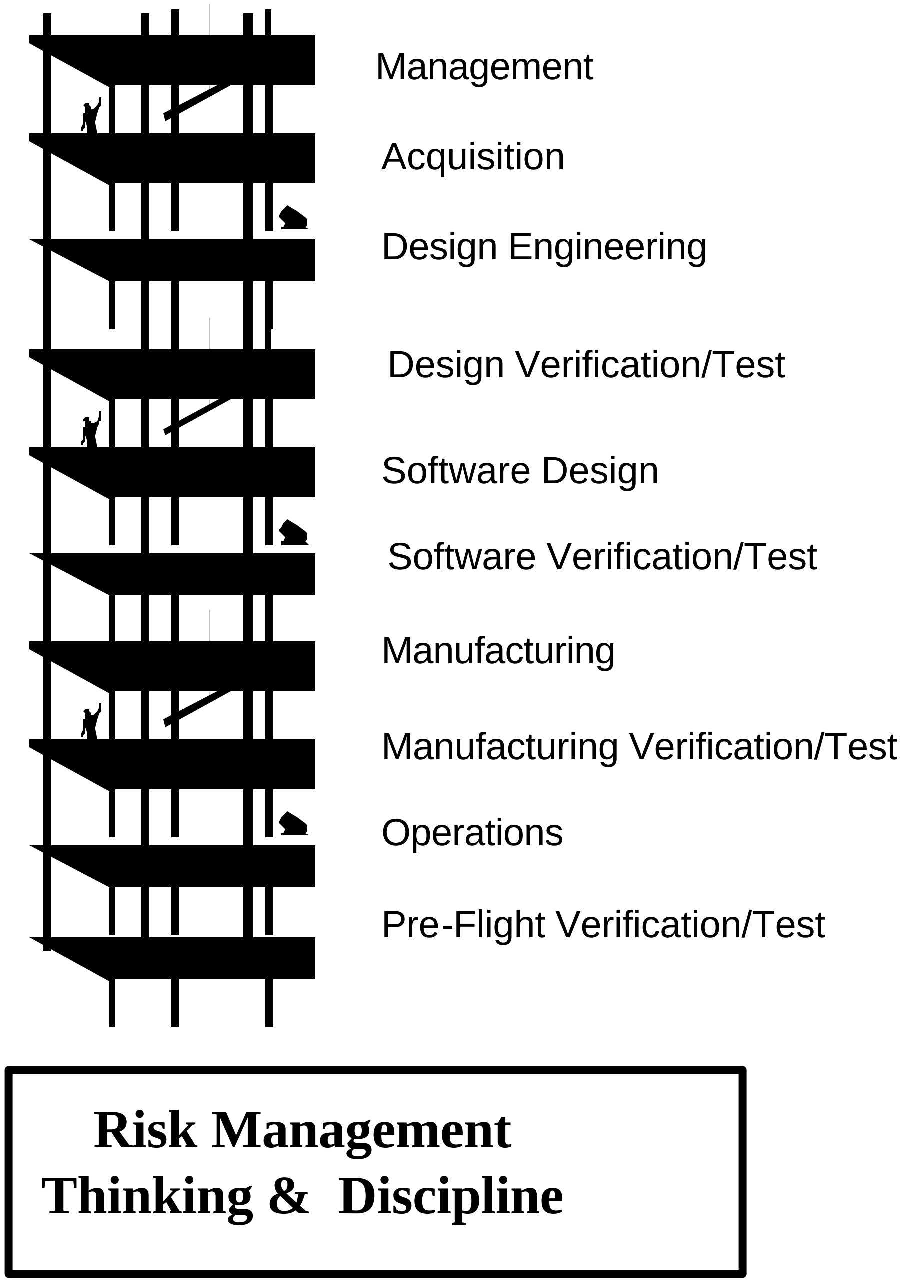


Figure 1.1

Complex aerospace systems require special care. The laws of physics demand certain rigor and thoroughness in design, manufacturing, test, and operations, regardless of vehicle acquisition approach. Even (or especially) faster/better/cheaper programs should adhere to the PBMA framework, achieving economies through innovative application of the PBMA philosophy which maximizes (program or contractor) management flexibility in implementing "best practices" and processes. The processes encompassed in the PBMA model (and its risk containment philosophy), while not guaranteeing mission success, will provide the best chance for a program to succeed.

Failure to properly implement documented assurance processes will always remain a possible source of program failure. Consequently, management vigilance, leadership, and visibility into assurance process implementation are essential. As discussed above, management assurance processes serve as the glue that binds together and provides discipline for overall PBMA implementation.

1.1.6 Report Structure

This report is comprised of three principal sections.

Section 1.0, "Introduction," describes the independent assessment background and overall methodology, ELV mission model, ELV Program office and SMA organizations, and the top-level SMA functions.

Section 2.0, includes a high-level ELV assurance process map that reflects the current (transitional) status of ELV program management relationships. This map provides a visual summary/aid to understanding the complex organization and document structure that supports ELV assurance functions. Specific observations and recommendations for improving ELV mission assurance are provided.

Section 3.0, "ELV Failure Case Studies and Gap Analysis," provides a synopsis of past launch vehicle failures and a brief description of probable cause or causes. This section then describes the process by which the review team developed evaluation criteria and subjectively assigned a "high," "medium," or "low" probability of whether the current stable of SMA practices and processes would have detected and/or prevented any of these historical failures.

Appendix A, "ELV Assurance Processes," provides a detailed description of the ELV launch services program at KSC. This includes a discussion of the current management approach and philosophy governing top-level policy guidance and, in particular, what key mission assurance functions and activities have been established and how they are being implemented within and among the various NASA HQ and Center program office and SMA organizations. This appendix is keyed to the PBMA model elements as described in figure 1.1.

1.2 ELV Background and Mission Model

1.2.1 Congressional Branch – Legislative History

The Commercial Space Launch Act (CLSA) of 1984 was established by Congress to create a framework within which ELV's, launch facilities, and commercial launch operations could be licensed. The primary purposes of the act are:

- Foster economic growth and entrepreneurial activity through the use of space for peaceful purposes
- Encourage the development of a private U.S. launch vehicle industry by simplifying and expediting the issuance of necessary licenses and facilitating the commercial use of government-developed space technology
- Designate the Department of Transportation to oversee, regulate, and license commercial launch operations.

An amendment to the Commercial Space Launch Act, November 1988 clarified commercial launch liability, launch preemption, and direct costs. In addition, the NASA Authorization Act of 1988 authorized the NASA Administrator to limit ELV contracts to U.S. sources.

The Launch Services Purchase Act of November 1990 directed NASA to procure commercially available U.S. expendable launch services and limited the use of the Shuttle for satellite delivery to those missions requiring the Shuttle's unique capabilities, i.e., crew support. The effect of this Act was to require procurement of launch service-to-orbit delivery with limited government insight and limited cost and pricing data.

The Commercial Space Competitiveness Act of November 1992 encouraged the continued use of commercial services/practices and required a NASA launch voucher demonstration program.

The amendment to the Commercial Space Launch Act of January 27, 1998 addressed the addition of "reentry" vehicles and operations, the use of space transportation services from U.S. commercial providers, and compliance with applicable safety standards. This amendment also established that space transportation services would be considered to be commercial items, i.e., a shift away from FAR Part 15 procurement and towards FAR Part 12 procurement requirements. This aspect of the CSLA is discussed in greater detail in appendix A, section A.2.

1.2.2 Executive Branch - National ELV Policies

The National Security Decision Directive (NSDD) 94 of May 1983 established ELV commercialization policy. NSDD 254 of December 1986 established a mixed fleet launch policy for government missions and directed NASA to procure ELV launch services.

National Space Transportation Policy of February 1988 and November 1989 reaffirmed and clarified NSDD 94 and also stated that NASA was to procure launch services directly from the private sector or the Department of Defense (DoD). The National Space Transportation Policy of 1994 stated that the DoD was to lead the improvement/evolution of the current ELV fleet while NASA was to develop the next generation of reusable launch vehicles.

Commercial Space Launch Policy of 1990 stated that U.S. government satellites were to be launched on U.S. ELV's unless exempted by the President. Additional guidelines adopted in 1991 stated that U.S. government agencies were to utilize commercially available space products and services. This policy also stated that the primary transport would be a mixed fleet of the Space Transportation System and ELV's through the 1990's. Additionally, the U.S. government was to maintain and improve the existing ELV fleet.

1.2.3 ELV Management History and Transition

<u>Prior to 1984</u>

Prior to the Commercial Space Launch Act of 1984, NASA was responsible to the Nation for the overall management and operation of the Delta, Atlas Centaur, and Scout ELV's. These programs were primarily accomplished by the contractor under traditional cost plus research and development (R&D) launch operation contracts utilizing a combination of contractor/government-owned facilities and equipment. However, NASA remained ultimately responsible and accountable for mission success.

<u>ELV Management at Glenn Research Center, Goddard Space Flight Center, and Langley Research Center</u>

Management and direction for these ELV programs were conducted at the Goddard Space Flight Center (GSFC) for the Delta vehicle, Glenn (formerly Lewis) Research Center (GRC) for the Atlas Centaur vehicle, and Langley Research Center (LaRC) for the Scout vehicle. Each Center had a project office staffed with highly experienced personnel supported by Center institutional organizations. Discipline expertise (propulsion, avionics, software, guidance, navigation and control, structures, parts, etc.) was available and often called upon to assist in mission assurance decisions. The vehicle project offices were typically staffed with discipline expertise with many years of experience. It was not uncommon to find government program personnel with equal or greater knowledge of the vehicle and its systems/subsystems than the contractors.

Created in 1959, the Delta Project, later renamed the Office of Launch Services (OLS) Project, was responsible for the design, development, and launch of the original Delta rocket. It is important to note that both LaRC and GRC employed similar ELV management approaches. With the introduction of the Commercial Space Launch Act Amendments, the U.S. Government was directed to procure commercial expendable launch services to the maximum extent possible. It was with this shift to commercialization that the Delta Project became the OLS Project. The OLS Project team possessed strong technical and programmatic skills spanning all core launch vehicle sub-system disciplines, spacecraft-to-launch vehicle integration, contract management, budget management, and overall program management. The mission of the OLS Project was the acquisition and management of high-quality and reliable small and medium class-based commercial launch services for use in the delivery of NASA or NASA-sponsored primary and secondary scientific payloads into orbit.

In the 1990's GRC was responsible for the overall management of commercial launch services for intermediate and large ELV's (Atlas Centaur/Commercial Titan III) for NASA and other government payloads. In the same time period, GSFC was responsible for the Delta and Pegasus launch vehicles. These roles ended on October 1, 1998, when GRC and GSFC responsibilities were transferred to KSC. GRC continues to support the industry by developing and testing new launch vehicle technologies and hardware through various cooperative programs.

<u>General NASA ELV Contract Oversight Approach Prior to 1989</u>

NASA civil servant and contractor personnel resident at the launch vehicle production facilities typically had extensive experience and knowledge of the vehicle, its systems, and contractor personnel and their capabilities. Resident personnel developed detailed knowledge of and actively participated in vehicle/system/subsystem design decisions, material review board (MRB) approvals, vehicle production reviews and tests, preship approvals, etc. Consequently, resident personnel gained insight sufficient to provide direction to the contractor that extended from parts level decisions to the decision to ship to the launch site Thus, resident personnel were the onsite “eyes and ears” for the project office, keeping them informed and making timely decisions on their behalf. The government/contractor team functioned much like an integrated product development team (IPDT) focusing on the ultimate goal of mission success.

<u>Transition to KSC</u>

In 1995 NASA conducted an Agency-wide zero based review (ZBR) to reassess all NASA HQ/Center roles and responsibilities. One result of this review was the decision to transition ELV management from multiple Centers to a single Center. The Agency determined that ELV acquisition and management belonged under the KSC operational launch center mission and the appropriate transition planning was begun.

In January of 1998 a transition plan that established KSC as the lead Center for acquisition and management of ELV launch services was signed by the Director of KSC and the Associate Administrator for Space Flight. The plan identified specific lead and performing Center roles and responsibilities. This included an implementation schedule for a staged transfer of intermediate expendable launch vehicle (IELV) launch services from GRC and medium, medium-lite, small, and ultra-lite class launch services from GSFC.

An important part of this transition involved the creation of strategic partnerships to take full advantage of the existing expertise at GSFC (Orbital Launch Services and Office of Flight Assurance), the Marshall Space Flight Center (Upper-Stages Project Office), and GRC (Launch Vehicle Project Office). The support and expertise embodied in these strategic partnerships include such critical mission assurance functions as independent review and assessment, mission integration, engineering analysis, and anomaly resolution.

Subsequent to January 1998, the transition proceeded on a mission-by-mission basis with KSC assuming all contract management and program authority effective October 1, 1998.

HQ ELV Requirements Office

The ELV Requirements Office in the Office of Space Flight (OSF) develops top level ELV acquisition and management policy and establishes overall manifest requirements.

1.2.4 Current KSC ELV Program

Objectives

The KSC ELV Program has established a set of top-level objectives in four primary areas: 1) customer requirements; 2) internal business processes; 3) learning and growth; and 4) financial. An expansion of these objectives is provided as follows:

Customer Requirements

- provide launch services to spacecraft customers anytime, anywhere
- reduce launch services cycle time
- continuously assess and improve customer satisfaction

Internal Business Processes

- develop, refine, enhance business processes
- partner with industry, academia, other NASA Centers, and other government agencies to lower risk and reduce cost

Learning and Growth

- develop and maintain expertise for acquisition and management of launch services
- develop a team environment which fosters learning

Financial

- reduce financial burden to the customer
- maintain project schedule and meet cost targets

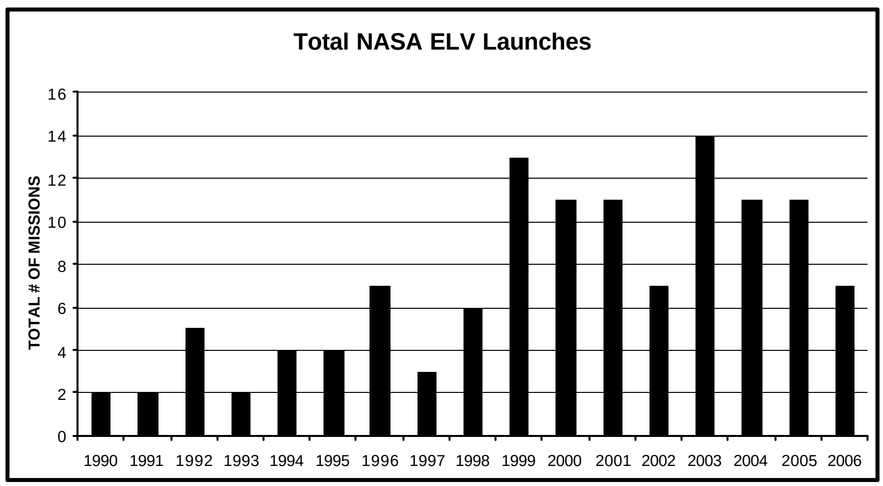
<u>Manifest/Work Content</u>

Within the context of the above stated objectives, the ELV Program faces a considerable challenge over the next several years. This is based on an increased launch rate, many launches taking place at Vandenberg AFB (imposing additional travel burden) and the requirement to manage launches from new, remotely located launch sites (Kodiak and Kwajalein Islands. Figures 1.2 and 1.3 show ELV total launch rate and total launches by site.

Figure 1.2

NASA ELV Total Launch Rate

EXPENDABLE LAUNCH VEHICLES



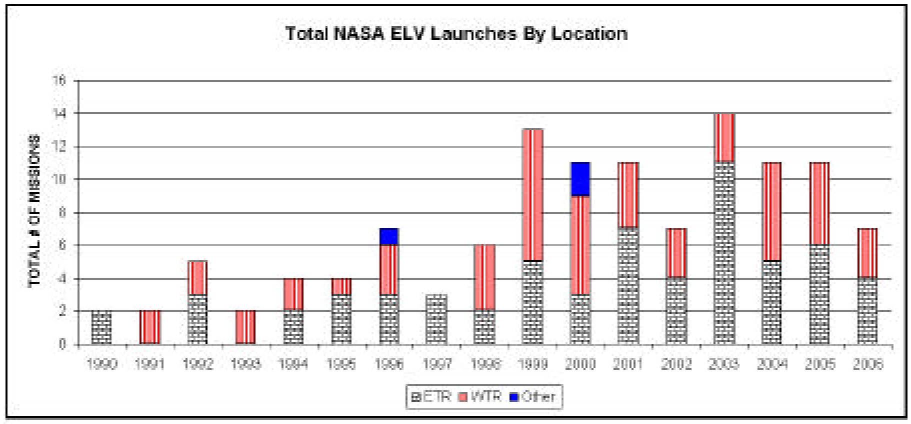
YEAR	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	TOTAL
NASA ELV Launches	2	2	5	2	4	4	7	3	6	13	11	11	7	14	11	11	7	120

Based on 6/4/99 Flight Planning Board *Updated 7/21/99* 9

Figure 1.3

NASA ELV Total Launches by Launch Site

EXPENDABLE LAUNCH VEHICLES



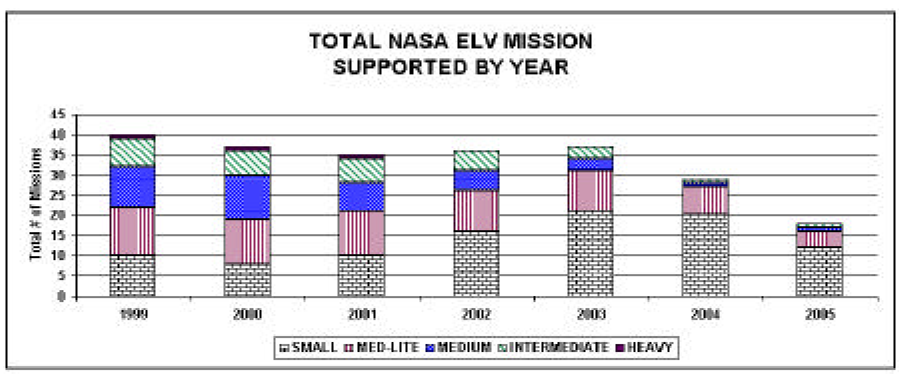
NUMBER	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	TOTAL
ETR	2	0	3	0	2	3	3	3	2	5	3	7	4	11	5	6	4	63
WTR	0	2	2	2	2	1	3	0	4	8	6	4	3	3	6	5	3	54
Other	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	3
TOTAL	2	2	5	2	4	4	7	3	6	13	11	11	7	14	11	11	7	120

Based on 6/4/99 Flight Planning Board ***Updated 7/21/99*** 10

Figure 1.4

NASA ELV Total Missions in Work

EXPENDABLE LAUNCH VEHICLES



CLASS	1999	2000	2001	2002	2003	2004	2005
SMALL	10	8	10	16	21	20	12
MED-LITE	12	11	11	10	10	7	4
MEDIUM	10	11	7	5	3	1	1
INTERMEDIATE	7	6	6	5	3	1	1
HEAVY	1	1	1	0	0	0	0
TOTAL	40	37	35	36	37	29	18

Based on 6/4/99 Flight Planning Board ***Updated 7/21/99*** 13

In addition to supporting a relatively high number of launches in 1999 and 2000, the ELV Program Office must also provide ongoing engineering and SMA support for future ELV missions. This is expected to be 40 and 37 missions in 1999 and 2000 respectively as shown in figure 1.4.

Staffing

Staffing is a critical issue, particularly in view of the increasing workload described in the previous section. Baselined in May 1998, the ELV and Payload Carrier Programs Office had a staff of approximately 213. This total was apportioned among the ELV Program Office (124) and the Payload Carrier Program Office (89).

The ELV Program Office staffing provided: Management (9), Engineering Services (44), Mission Integration (23), Telemetry and Communication Services (12), Program Integration and Contract Technical Management (11), SMA (11), Procurement (8) and Comptroller (6).

The May 1998 baseline was developed to support a sustained launch rate of approximately six to eight launches per year with surge capability (overtime/comp-time) up to ten launches per year for brief periods. The current ELV manifest has a sustained launch rate of approximately 12 launches per year with peaks up to 17 launches. As a result, the ELV staffing requirements for the ELV Program Office have grown to 159 full time equivalents (FTE's), primarily in the Engineering Services and Mission Integration functions. The following tables provide a comparison between the number of individuals currently involved in assurance related activities with the number of individuals performing similar tasks at GSFC and GRC prior to transition of ELV program management to KSC.

KSC ELV Assurance Related Staffing	**Current**
Civil Servants (CS) Engineering and Integration Mgmt	4
CS Engineering	51
CS Mission Integration	32
CS SMA	13
ELV Assurance Total Civil Servants	100
Contractors (Assurance Area)	39
Total ELV Assurance Personnel	**139**

ELV Assurance Personnel Prior to Transition		
	GSFC 1997	**GRC 1995**
Civil Servant Engineering	51	82
Contractor Engineers (incl. SMA)	29	45
Civil Servant SMA	5	6
ELV Assurance Total	85	133
Total ELV Assurance Personnel = 218		

Notwithstanding the staffing increases a number of key positions remain vacant. The most significant vacancies are in the KSC ELV Program Office, ELV Launch Services Directorate, and the Mission Integration and Customer Division. In addition to the vacant positions, there are concerns regarding the loss of experience base and the need for maintaining (or re-establishing) an appropriate workforce skill mix.

Placing the staffing issue in historical perspective, at the time when the ELV program responsibilities were transitioned to KSC, GSFC and GRC had a combined staff of approximately 220 ELV-experienced personnel devoted to providing launch service support for the NASA ELV programs. Of the existing KSC core staff, less than 10 percent of the previous approximate 220 ELV Center staff migrated to KSC.

1.2.5 Current ELV Contracts, Prime Contractors, and Principal Manufacturing Sites

Intermediate Expendable Launch Vehicle Services (IELVS) Class

- Atlas (IIA/IIAS/AIII) - Lockheed Martin, Denver, Colorado
- Delta III - Boeing, Huntington Beach, California, and Pueblo, Colorado

Medium Expendable Launch Vehicle Services (MELVS) Class

- Delta II - Boeing, Huntington Beach, California, and Pueblo, Colorado

MED-LITE (ML) Class

- Taurus XL - Orbital Sciences Corporation, Chandler, Arizona, and Dulles, Virginia
- Delta (D3 and D4) - Boeing, Huntington Beach, California, and Pueblo, Colorado

Small Expendable Launch Vehicle Services (SELVS) and Ultra-lite Expendable Launch Vehicle Services (UELVS) Class

- Pegasus - Orbital Sciences Corporation, Chandler, Arizona, and Dulles, Virginia
- Athena I - Lockheed Martin, Denver, Colorado

- LK0 - Coleman Research Corporation, Orlando, Florida

An expanded discussion of the present ELV launch service contracts is provided in Section A.2.

1.2.6 Current ELV Launch Sites

The launch locations which support ELV launches include:

- Eastern Range (Cape Canaveral Air Force Station)
- Western Range (Vandenberg Air Force Base)
- Wallops Island
- Kodiak Island
- Kwajalein Island

1.3 KSC ELV and SMA Organizations

The organization and management structures are provided in the figures 1.5 and 1.6.

Figure 1.5

44 4

ASSOCIATE DIRECTOR FOR
ELV, SUPPLIER QUALITY & INSTITUTIONAL

OTTO, GLENN Associate Director 867-3392 HQ 3517
Vacant Deputy Director HQ 3517
Vacant Secretary 867-3392 HQ 3517
LES MCGONIGAL Range Safety Manager 867-3163 HQ
SANDY DUNFEE Mgt. Support Asst. HQ 3517
RUTHA WILLIAMS Mgt. Support Asst. 853-7991 CCAFS E&O

11

ELV FLIGHT ASSURANCE DIVISION

Staubus, Calvert Chief CCAFS E&O

MEEKS, SAM
KING, ROYSTAN
WITTER, ROBYN

HAMMOND, ROBERT QA Lead
WALKER, DIANE VAFB QA
BURNS, LINDA
GONZALEZ, JOSE
LELAND, LEE
LABIAK, ROBERT
NOONAN, EDWARD
ROEDER, JOE

NEWSOME, DOUG VAFB SAFETY

S&MA SUPPORT CONTRACTOR

ARRIGO, TONY (UNISYS, Chandler, Az)
AVILLAR, FRANK (SAIC, KSC)
HARRISON, WILLIAMS (SAIC, Denver, Co)
Vacant (UNISYS, Pueblo, Co)
STONE, RANDY (UNISYS, Hunt. Beach, Ca)
BARNA, FRANK (SMI, VAFB)
WHITE, DALLAS (SMI, VAFB)
BOLTEN, HERB (SMI, VAFB)

19

SUPPLER QUALITY DIVISION

SMITH, TERRY Chief 867-1419 HQ 3513
VARGAS, K. Secretary

BAILEY, JUD
COFFMAN, STEVE
DEANE, ED
GRISSOM, KEN
SWANSON, JAMES
TALLEY, CHARLES

BEST, RON NSLD
YOUNG, JAMES NSLD

ARMSTRONG, BOB LA
BAILEY, MOMTY CT
BOLEN, DENNIS CA
HILL, RAY CA
HYDE, KEN AL
MACK, ANDRE CT
MACRI, GEORGE IL
ROSS, TIM CO
WILDER, RICK AZ

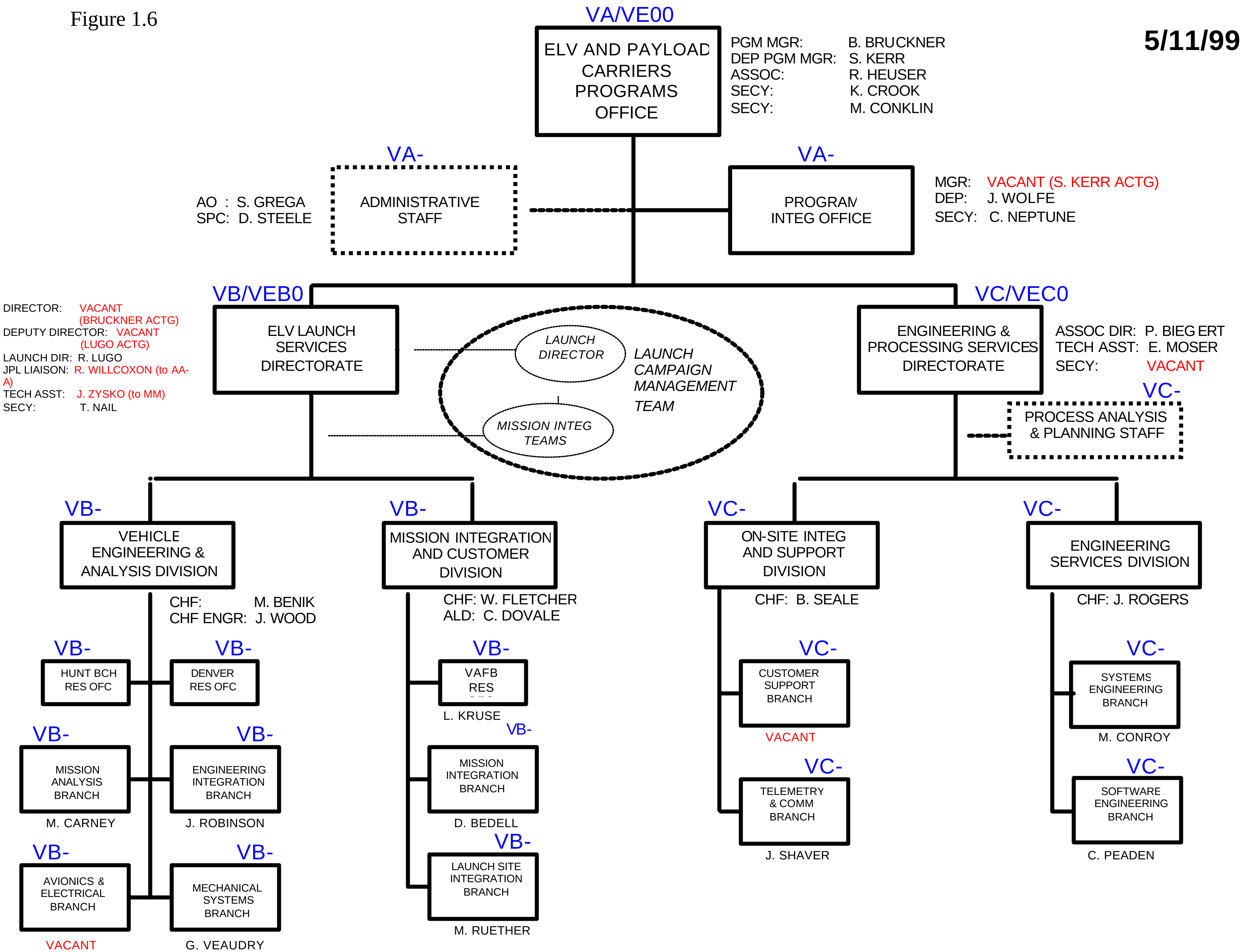
10

INSTITUTIONAL SAFETY D IVISION

GOODIN, RONNIE Chief 867-4493 HQ

DWYER, TOM
ENSIGN, CHARLES
FACEMIRE, DAVID
MEEKER, RON
RIDDLE, WILLIAM
SWIHART, PHILLIP
TURNER, ROBERT
VYCITAL, DON
WILLIAMSON, TIM

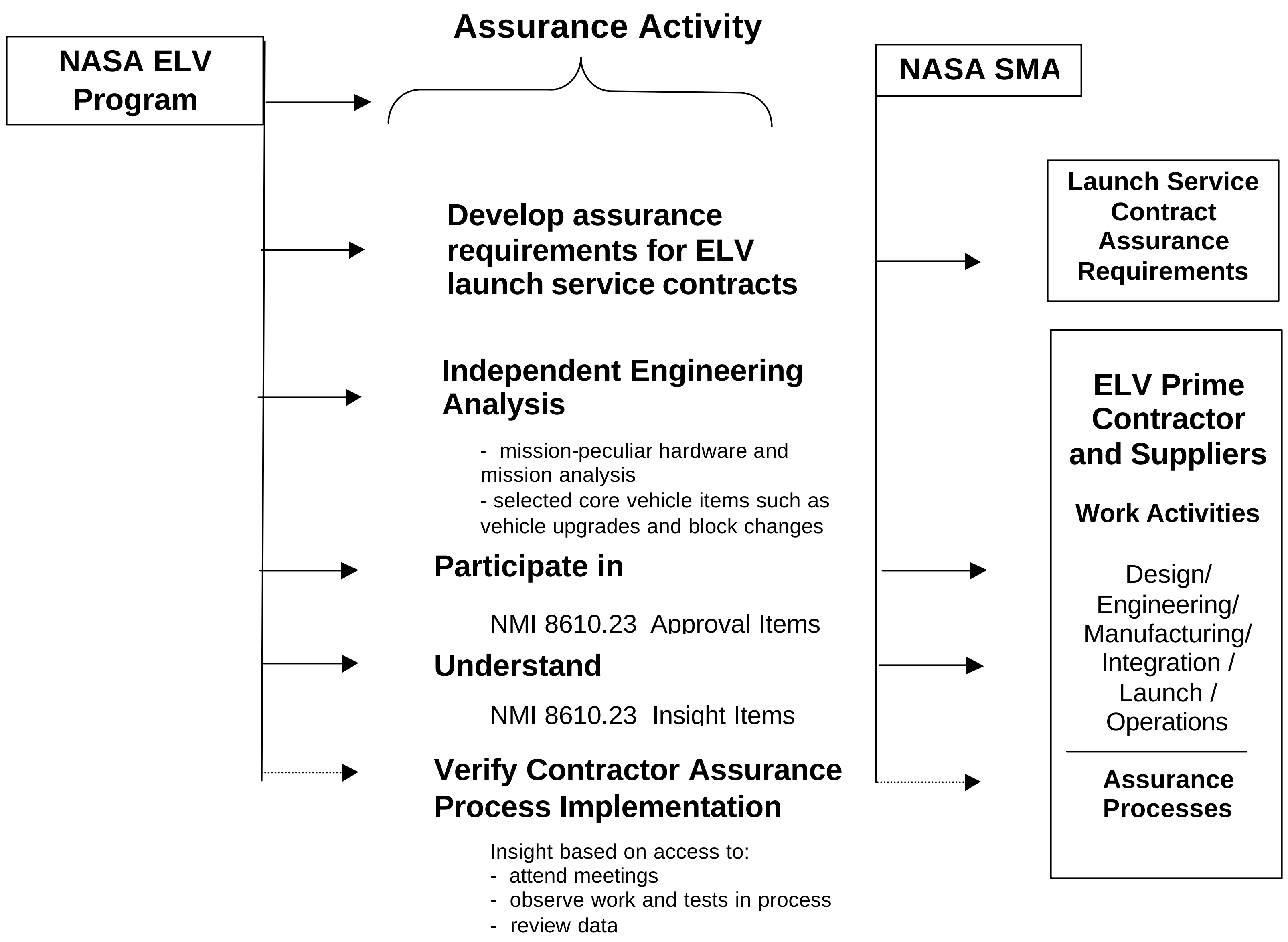
Figure 1.6


5/11/99
VA/VE00
ELV AND PAYLOAD CARRIERS PROGRAMS OFFICE
PGM MGR: B. BRUCKNER
DEP PGM MGR: S. KERR
ASSOC: R. HEUSER
SECY: K. CROOK
SECY: M. CONKLIN
VA-
AO : S. GREGA
SPC: D. STEELE
ADMINISTRATIVE STAFF
VA-
PROGRAM INTEG OFFICE
MGR: VACANT (S. KERR ACTG)
DEP: J. WOLFE
SECY: C. NEPTUNE
VB/VEB0
ELV LAUNCH SERVICES DIRECTORATE
DIRECTOR: VACANT (BRUCKNER ACTG)
DEPUTY DIRECTOR: VACANT (LUGO ACTG)
LAUNCH DIR: R. LUGO
JPL LIAISON: R. WILLCOXON (to AA-A)
TECH ASST: J. ZYSKO (to MM)
SECY: T. NAIL
LAUNCH DIRECTOR
LAUNCH CAMPAIGN MANAGEMENT TEAM
MISSION INTEG TEAMS
VC/VEC0
ENGINEERING & PROCESSING SERVICES DIRECTORATE
ASSOC DIR: P. BIEGERT
TECH ASST: E. MOSER
SECY: VACANT
VC-
PROCESS ANALYSIS & PLANNING STAFF
VB-
VEHICLE ENGINEERING & ANALYSIS DIVISION
CHF: M. BENIK
CHF ENGR: J. WOOD
VB-
HUNT BCH RES OFC
VB-
DENVER RES OFC
VB-
MISSION ANALYSIS BRANCH
M. CARNEY
VB-
ENGINEERING INTEGRATION BRANCH
J. ROBINSON
VB-
AVIONICS & ELECTRICAL BRANCH
VACANT
VB-
MECHANICAL SYSTEMS BRANCH
G. VEAUDRY
VB-
MISSION INTEGRATION AND CUSTOMER DIVISION
CHF: W. FLETCHER
ALD: C. DOVALE
VB-
VAFB RES
L. KRUSE
VB-
MISSION INTEGRATION BRANCH
D. BEDELL
VB-
LAUNCH SITE INTEGRATION BRANCH
M. RUETHER
VC-
ON-SITE INTEG AND SUPPORT DIVISION
CHF: B. SEALE
VC-
CUSTOMER SUPPORT BRANCH
VACANT
VC-
TELEMETRY & COMM BRANCH
J. SHAVER
VC-
ENGINEERING SERVICES DIVISION
CHF: J. ROGERS
VC-
SYSTEMS ENGINEERING BRANCH
M. CONROY
VC-
SOFTWARE ENGINEERING BRANCH
C. PEADEN

1.4 ELV Top-Level Assurance Functions

The organizations described in the previous sections are chartered to provide a basic critical set of ELV mission assurance activities which typically span the program development life-cycle. They begin with assuring that appropriate mission assurance requirements are established for the various launch service contracts and extend through the conduct of independent engineering analyses, participation (approval or insight per NMI 8610.23) in key program development decisions, and onsite or in-plant verification that prime contractor and supplier mission assurance processes are adequately implemented. These top-level assurance activities are summarized in figure 1.7.

Figure 1.7 NASA ELV Assurance Activities Top Level Functions



2.0 ELV Assurance Processes

2.1 ELV Assurance Process Mapping

Based on data and information gathered during the Discovery phase of the assessment, the review team constructed a high level ELV assurance process map (figure 2.1) to assist in understanding the complex management and documentation structure that supports the assurance functions summarized in figure 1.7 of the previous section.

Figure 2.1 contains heavy arrows (assurance vectors) which represent the delivery or implementation of assurance activities. Table 2.1 provides a key to assist in understanding the who, the how, and the what associated with each arrow. The complexity of figure 2.1 reflects the current (in transition) status of ELV program management relationships.

The assurance functions (the what's) are addressed in greater detail in appendix A which tracks the assurance model described in section 1.0, and provides an expanded discussion of each element.

Figure 2.1 Top-Level ELV Assurance Process Map "How & Who"

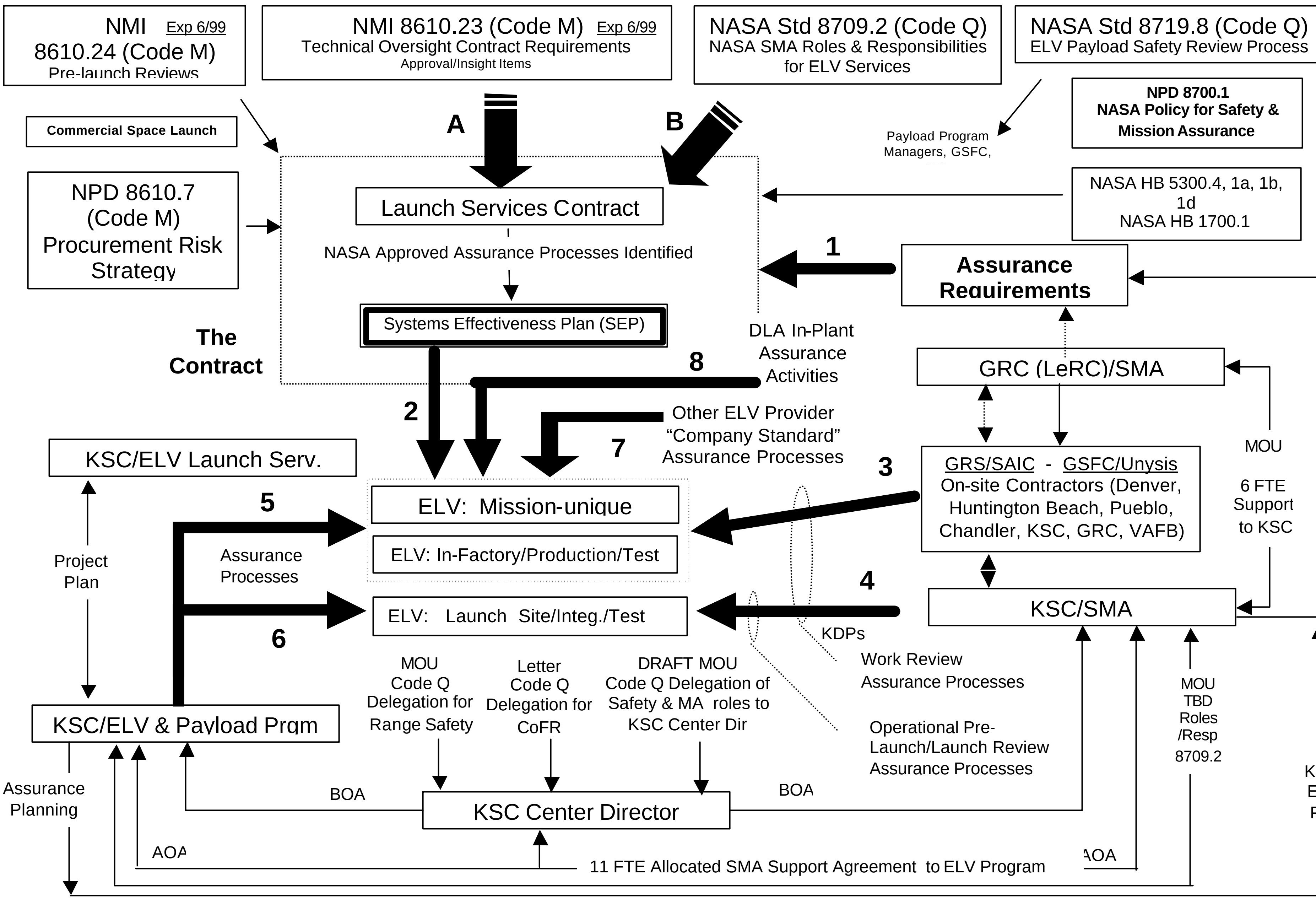


Table 2.1 Assurance Map – Description

Assurance Vector	Who/Where (organization)	How	What (Assurance Function)
A	NASA Office of Space Flight	Publication of NASA policy directives	NASA HQ/OSF policy document defining assurance provisions to be incorporated in ELV launch service contracts
B	NASA Office of Safety and Mission Assurance	Publication of NASA policy directives	NASA HQ/SMA policy document defining assurance activities to be implemented in connection with ELV launch service contracts
1	Representatives from the ELV Program Office and the SMA organization	Participation in Acquisition Source Evaluation Board Activity	Assurance Requirements Planning
2	Contractor	Contract Deliverable	Contractually binding assurance requirements which the contractor develops and submits to NASA as a Contract Data Requirements List (CDRL). May be titled Systems Effectiveness Plan, Quality Plan, or some other contract appendix or attachment.
3	In-the-factory NASA SMA Flight Assurance Managers (FAM's). Contractors located at Denver, Huntington Beach, and Chandler. Plans are to fill a vacant position at Pueblo.	NASA factory-based FAM's are currently supported by a complex network of MOA's, contracts, and resource transfers from KSC to GRC or GSFC.	Implementers of flight assurance functions: 1) participating in engineering decisions without approval authority; 2) understanding how engineering decisions are made. Maintain insight on production/manufacturing status and issues. Review nonconformance records. Manage or coordinate DCMC quality assurance support activities in the factory (see Arrow #8).

Table 2.1 (continued)

Assurance Vector	Who /Where (organization)	How	What (Assurance Function)
4	KSC Safety and Mission Assurance Director	Participate in launch readiness reviews and, based on the data gathered below, provide the SMA position on launch readiness.	The ultimate KSC SMA assurance function is to gather the information and understanding necessary to support the CoFR.
	Flight Assurance Managers	Participate in Acceptance Reviews, Program Reviews, ERB's, MRR, LRR, FRR, launch countdown, etc. KDP's in work to document flight assurance processes	
	Quality Assurance Specialists	Surveillance of contractor work activities at the launch site. Participate in pathfinder activities and reviews. KDP's that document quality assurance processes	
5	In-factory resident office staff. Individuals are located at Denver, Huntington Beach, Pueblo, and Chandler.	Participate in engineering and test and verification activities with approval authority for NASA mission-unique hardware and software. Residents maintain awareness of the basis for core vehicle engineering decisions. Offices are composed of NASA civil servants and contractor support staff.	In support and under the direction of KSC ELV Program Office, provide engineering oversight and monitoring of ELV manufacturing and production activity.

Table 2.1 (continued)

Assurance Vector	**Who /Where (organization)**	**How**	**What (Assurance Function)**
6	KSC ELV Program Office - Engineering - Mission Integration	KSC-based engineering and mission integration personnel participate and manage mission-unique hardware and software design, verification, and test activities. The same staff provides an oversight engineering management role for core vehicle hardware and software. Key work processes include the Engineering Review Board and the Mission Integration Team(s).	Exercises ultimate responsibility for ELV mission success.

2.2 Observations, Findings, and Recommendations

2.2.1 ELV Management Assurance Processes – A Change of State

The following table describes key programmatic attributes before and after ELV management transition from GSFC/GRC to KSC.

Condition A		**Condition B**
ELV managed at GSFC and GRC with ~220 FTE involved in assurance activities (contractors & civil servants)		Managed at KSC with approximately 139 FTE involved in assurance activities (contractors & civil servants)
Many employees with high levels (30+ years) of ELV experience – program management and design center culture	**ELV Transition**	10 to 15 years of aerospace engineering or management experience. Limited or no ELV experience – primarily launch and operations center culture
Extensive systems-level knowledge/detailed component or box-level knowledge of the vehicle		General systems-level knowledge but little or no knowledge at the box level of the vehicle
36 SMA flight assurance and quality assurance people (supported by institutional engineering organizations)	**Pre-1998 to Present**	25 flight assurance and quality assurance personnel (civil servants and contractors)
FAR Part 15 Procurement: Mission assurance requirements written into solicitation and included in contract.		FAR Part 12 Procurement (Commercial Item), tailoring and waivers needed to add specific assurance requirements and audit authority.
Mature set of launch vehicles with selective upgrades	***TRENDS***	Increasing number of launch vehicles (new and modified) to qualify and understand.
20 flights in-flow at any one time		35 to 40 flights in-flow at any one time
Three operational launch sites (KSC/VAFB/Wallops)		Five operational launch sites (KSC/VAFB/Kodiak/Kwajalein/Wallops)
Four to seven launches per year		10 to 15 launches per year
Approximately 98% NASA success rate over last 47 launches (OSF/Code MV presentation Aug. 10, 1999)		**?** **success rate … to be determined**

We are still seeing the results of condition A. We are moving toward condition B. Will we be able to maintain the launch success rate given the significant changes in ELV management?

2.2.2 General Observations

The review team has developed the following general observations and comments.

1. Perception that 97.9% Success Rate means No Reason for Concern

NASA's overall success rate over the last 47 ELV launch attempts has been excellent. However this record reflects, to a large extent, the success of past GSFC and GRC ELV management practices. While eight of the last launch attempts have occurred since the transition of program management to KSC, the success of these recent missions cannot be viewed as validation or certification of KSC ELV assurance processes since an ELV mission typically takes 30 months from initiation to launch. Since the success rate is inherited and given that the KSC ELV organization represents a new team with an evolving management structure and approach, there is no cause for complacency.

2. Expectation for Mission Success

The ELV program officials interviewed during this review expressed a consistent view that 100% mission success is the management expectation, regardless of payload dollar value, complexity, visibility, etc. This expectation is obviously in conflict with the inherent risk acceptance philosophy of procuring commercial launch services. ELV program officials at KSC are aware that enormous effort and expense is devoted to assuring that spacecraft and payloads are developed as robust and reliable systems. At the same time only relatively thin assurance insight is acquired for the launch vehicle systems and sub-systems. Hence, the KSC program response has been to provide basically the same level of support and insight independent of total mission cost.

3. ELV Program – Scope and Magnitude of the Job

The scope and magnitude of the ELV Program management task and the complexity and difficulty of the transition task was significantly larger than initially conceived at the time of the NASA zero-base review. As stated by one interviewee, KSC was formerly "just the launch site…now it is the management center."

4. Transition to KSC Led to a Significant Loss of ELV Expertise and Experience

Several individuals interviewed expressed the view that engineering "box-level knowledge" has given way to, at best, a "systems-level knowledge." Indeed, it is not clear to what extent ELV Engineering has actual or real system-level knowledge for all of the different launch systems currently in use or in development.

5. More Small Payloads – More Engineering, Integration and Assurance Work

As NASA managers moved toward smaller payloads (better/faster/cheaper) the workload for ELV engineering and integration increased steeply. Single large missions are now replaced by multiple smaller missions each requiring engineering, integration, and assurance support. Each payload wants the same thing – "mission success."

6. Engineering Review Board (ERB)

The ERB process facilitates good systems engineering and provides for excellent communication flow within the KSC engineering organization. Interviews suggest that communication between field engineering organizations and KSC engineering is an area for improvement. KSC/SMA and ELV Program management should work to assure consistent SMA participation in the ERB process.

7. Mission Integration Teams (MIT's)

While the Mission Integration Team (MIT) approach is an obvious strength, it is also very demanding of personnel resources.

8. Procurement

The KSC procurement source board is making an excellent effort to incorporate appropriate assurance provisions in the new NASA Launch Service (NLS) procurement. Given the constraints of commercialization the ELV procurement source boards are making excellent efforts to incorporate appropriate NASA assurance provisions.

9. ELV Program – SMA/ELV Communication

KSC/SMA and ELV Program communication and coordinated planning have not been areas of strength. SMA participation and input in the NMI 8610.23 revision activity was not evident. SMA/ELV staff may not be receiving the necessary information to perform their independent assurance function (PAD, test and vehicle integration event schedules, etc.).

10. Importance of Excellent Work Instructions

The Lockheed Martin senior manager for Pad 36 expressed the view that excellent work instructions are the most important assurance process one can have. This underscores the importance associated with the need for KSC ELV and SMA organizations to develop excellent work instructions at the KDP level and at the implementation plan level.

11. Government to Contractor Communications

The depth and breadth of cooperation varies depending upon the launch vehicle manufacturer with Boeing/Delta representing the best level of coordination/information exchange and communication.

12. Atypical ELV Acquisition

The case of Titan II and Principal Investigator (PI) acquisitions (acquisition - taken to mean providing NASA resources to acquire an ELV launch) is important to consider. It is not clear what NASA policy directives apply. There is no documented process which describes MOA interfaces, coordination, or the specification of assurance requirements for ELV's when provided by the Department of Defense.

On June 19, 1999, QuikSCAT was launched on a Titan IIA using a new procurement system called the "Rapid Spacecraft Acquisition" process, which was instituted by GSFC. QuikSCAT's rapid acquisition was needed when the NASDA Scatterometer (NSCAT) satellite lost power in June 1997 and created a gap in earth science ocean and wind speed data. The new procedure accelerated the process through which NASA purchases and develops satellite systems and used many off-the-shelf technologies and practices from the commercial spacecraft industry. QuikSCAT was the fastest that any NASA spacecraft of this complexity was built, integrated, and tested (a record 11-month time frame). While QuikSCAT continues flight success, the project violated many ELV procurement risk strategy steps, technical oversight requirements, and ELV assurance processes. NASA management needs to examine rapid or emergency procurements and determine how to apply sensible processes to meet the ELV mission assurance needs.

2.2.3 Recommendations

For purposes of clarity the principal recommendations for this section of the report have been organized into three main areas: 1) Top Level ELV Policy; 2) Resources, Roles, and Responsibilities; and 3) Mission Assurance Processes.

<u>Top Level ELV Policy (P)</u>

	Responsible for Action (Bold=lead)	**Recommended Action**	**Reference Observations**
P1	**HQ/OSF,** HQ/OSMA, KSC/ELV, KSC/SMA	Establish guidance-level document (NPG) that defines the management system, processes, requirements, and responsibilities for implementing NMI 8610.23. This NPG would define the depth and breadth of core vehicle insight requirements and the extent of independent analysis required on the core vehicle.	The spirit and intent of insight and oversight defined in NMI 8610.23 was developed by NASA Headquarters with strong influence from both GRC and GSFC. The document was written for an experienced ELV engineering culture and management model that does not exist today. As evidenced by the very high success rate, the former ELV Centers fully understood, (based on 20-plus years of ELV management and program experience) what was required for mission success, as well as how to implement insight and oversight functions. NMI 8610.23 provided GRC and GSFC ELV managers with the flexibility to do the things they needed to do to assure mission success. This same flexibility (an asset in 1987) without the broad ELV knowledge base (and adequate resources) becomes a handicap in 1999. The KSC ELV Program office needs better definition and greater specificity in either a revised NMI 8610.23 or a second tier document (NPG) which assists in the implementation of ELV technical oversight. Numerous interviews cited the disconnects between NASA management statements regarding better/faster/cheaper programs, risk taking, performance-based contracting, commercial launch service acquisition, and the expectation for 100% mission success. "There is a lack of clarity on what to do to mitigate risk on each individual mission and what level of risk is acceptable."

Expand HQ/OSF Policy Guidance

Top Level ELV Policy (P) (continued)

	Responsible for Action (Bold=lead)	Recommended Action	Reference Observations
P2	**NASA Chief Engineer** HQ/OSF, HQ/OSMA, KSC/ELV, KSC/SMA, HQ/AE	Establish an ELV mission assurance/risk management board for each mission. This board will develop an internal "contract" or documented agreement defining the degree and depth of assurance core vehicle insight and independent analysis required for a given mission based on cost, complexity, visibility, scientific value, etc. It may be possible to implement this function as an adjunct to the Flight Assignment Board. ***Establish Mission Assurance Risk Board***	The objective is to provide clear guidance for using limited KSC assurance resources (time, people, skills) to protect NASA's high-value payloads. The board could develop assurance portfolios (i.e., Portfolio A, B, or C) which would vary, for example, in the degree and depth of independent analysis, extent of supply chain audit, core vehicle review, etc. This approach is similar to that defined in NPD 8610.7 which assigns risk categories to individual payloads to assist in assigning the launch vehicle.
P3	**HQ/OSMA,** HQ/OSF, KSC/ELV, KSC/SMA	Establish a top level SMA policy directive (NPD) that defines SMA roles and responsibilities, incorporating existing SMA/MOU's and SMA letters of delegation. Document should be developed in coordination with development of NPG recommended in P1. This top level SMA/ELV document should build upon the guidelines contained in NASA Std. 8709.2, "NASA SMA Roles & Responsibilities for ELV's." *Note: HQ/OSMA plans to have a policy prepared (in coordination) by January 2000.* ***Establish a NASA SMA /ELV Assurance Policy Directive***	The array of governing laws, directives, standards, etc., (see Figure 1.2) creates obvious confusion at the implementation level. In addition, the one document most often mentioned in interviews as the "governing document," NMI 8610.23, was universally described as too vague, lacking in specificity with respect to depth and breadth of involvement in approval and insight activities. The review team recognizes that the intricate map of relationships and agreements reflects a transition that was based on using existing structures whenever possible to fill assurance voids. It certainly does not reflect well-conceived management planning. As noted above, a major shortcoming in the Headquarters guidance (both OSF and OSMA) is the absence of sufficient guidance with respect to depth and breadth of assurance expected for missions of differing program importance and dollar value. The KSC-based ELV Program engineering organization in large measure attempts to treat all missions with the same level of attention and care. However, lacking guidance, decisions to do more or less (e.g., analysis) are made on a case-by-case basis by lower level managers.

<u>Top Level ELV Policy</u> (P) (continued)

	Responsible for Action (Bold=lead)	Recommended Action	Reference Observations
P4	**HQ/L,** HQ/G, HQ/OSF, HQ/OSMA	Initiate/maintain a Headquarters dialogue with Congress to assure that CSLA legislation or revisions do not constrain NASA's ability to establish necessary assurance requirements and/or restrict NASA's ability to verify contractor implementation. ***Provide a consistent NASA position on CSLA amendments and revisions***	NASA senior management needs to provide input to appropriate committees in the Congress to assure that CSLA provisions do not restrict or inhibit NASA (or other government customers) from establishing necessary assurance requirements to protect high-value government assets. While restricting assurance requirements to a single quality process makes business sense for fully insured commercial launch service providers and their commercial customers, it makes no sense for scenarios where the mission is a one-of-a-kind, high scientific value or national defense payload.

Resources, Roles & Responsibilities (R)

	Responsible for Action (Bold=lead)	**Recommended Action**	**Reference Observations**
R1	**HQ/OSF** KSC Center Director	R1a. Resolve skill mix and staffing issues consistent with management expectations for mission success.	The ELV program at KSC is staffed by a dedicated, committed, and hardworking staff of professionals. The "best of the best" approach, integrating the three engineering cultural norms, represents a good approach. An excellent, but smaller than hoped-for, cadre of professionals has been recruited from GSFC and GRC to complement a small core group of KSC-based ELV managers. (The migration of individuals from GRC and GSFC represents less than 10% of the approximately 250 ELV professionals previously working ELV's at those locations.) However, the transition and staffing in all skill areas remains a work in progress.
		R1b. Increase ELV Program staffing and contractor support commensurate with mission model. Reinvigorate the action to recruit experienced GRC and GSFC personnel.	The magnitude of the ELV management job is much larger than simply procuring a commercial launch service. Current ELV Program engineering and integration staff are under high stress levels, the staff is overworked, and according to interviews, "lots of comp time gets swept off the books, and there is too much travel." ELV Program and KSC/SMA/ELV management structures are (have been) full of vacancies and "acting managers" for an extended period of time. The staffing levels, the magnitude of the job, and the expectations for mission success are not compatible.
		R1c. Increase SMA staffing commensurate with the need for independent assessment and verification of contractor process implementation.	SMA/ELV staffing does not match the expectations for knowledgeable, informed independent assessment, and does not match the expectation that verification has been formally conducted to assure contractor assurance process implementation.

Increase staffing levels and align skill mix at KSC to be consistent with mission model and expectations

Resources, Roles & Responsibilities (R) (cont.)

	Responsible for Action	Recommended Action	Reference Observations
R1 cont	**HQ/OSF** KSC Center Director	R1d. Fill critical management vacancies as soon as possible.	Both OSMA and OSF management attention has been diluted and distracted during (and throughout) the transition of ELV responsibilities to KSC. This is evident in the state of confusion regarding mission success expectations, and in the development and interpretation of appropriate Headquarters policy guidance, staffing, and funding. However, the recent series of OSF meetings to address ELV program staffing and resource shortfalls and the recent KSC/SMA ELV assurance manager conference are positive indicators of renewed management attention.
		R1e. Consolidate flight assurance management contracts to KSC and establish stable long-term relationships with key in-plant representatives.	Specific staffing level needs should be assessed relative to the previous (prior to transition) workforce at GSFC, GRC, and KSC and against the current ELV management and mission model. Significantly fewer staff, with less ELV experience, cannot possibly provide assurance levels similar to pre-transition given the significantly higher work load, i.e., 35-40 missions in-flow at any time with 10-15 launch campaigns per year.

Increase staffing levels and align skill mix at KSC to be consistent with mission model and expectations

Resources, Roles & Responsibilities (R) (cont.)

	Responsible for Action	Recommended Action	Reference Observations
R2	**KSC Center Director** KSC/ELV Program, KSC/SMA ***Define ELV Program and SMA/ELV Roles and Responsibilities***	R2a. In concert with Recommendation, R1, formally review the distribution of roles and responsibilities of ELV Program and ELV/SMA personnel. R2b. Clarify roles and responsibilities of KSC/SMA and KSC/ELV organizations.	Throughout the review individuals interviewed expressed frustration with the lack of clarity in the definition of assurance roles and responsibilities. It was noted that a significant amount of what are traditionally considered to be quality assurance/flight assurance functions are being performed by KSC ELV engineering personnel. The defacto delegation of assurance activities to the program/project office removes or invalidates one of the principal functions of an SMA organization - to provide an independent perspective and assessment of overall program management and direction.
R3	**KSC/SMA** ***Consolidate all SMA/ELV Assurance Capabilities to KSC***	Consolidate ELV/SMA capabilities to KSC.	KSC/SMA needs to accept full responsibility for the ELV SMA requirements and eliminate the MOU with GSFC. If KSC continues to rely on GSFC for support, they will be slow to develop the in-house expertise and experience needed. Continued reliance on GSFC does not contribute to blending of the GRC, GSFC, and KSC operating philosophies.
R4	**KSC/SMA and KSC/ELV** ***Document Critical ELV Processes***	Develop a system of coordinated KDP's to implement (and flow-down) program and mission assurance responsibilities in alignment with headquarters' policy directives. The KDP's must show direct traceability to Headquarters policy directives NMI 8610.23 and NASA STD. 8709.2.	Throughout the SMA and ELV program organizations at KSC, many important (critical) assurance and management processes remain undocumented and excluded from the scope of the ISO certification which incorporates many peripheral/administrative processes. This example underscores the common misperception that once an organization is ISO certified, the organization has documented and is implementing all of the right processes in the right way. In addition, careful attention must be given to the scope of the certification as not all critical processes or segments of the organization may be in scope.

Mission Assurance (A) Processes

	Responsible for Action	Recommended Action	Reference Observations
A1	**KSC/SMA and KSC/ELV Program**	Develop a detailed operational plan(s) to implement (and flow-down) program and mission assurance responsibilities in alignment with Headquarters policy directives and appropriate KDP's.	The review team observed that many KDP's are very high level, consisting of little more than a flow diagram. These directives are subject to individual interpretation. In such cases there exists a need to develop detailed implementation plans. If the KDP's can be revised to increase content then an implementing plan may not be necessary.
A2	**KSC/SMA**	Establish an individual Mission Assurance Manager (MAM).	No single individual seems to understand the full set of assurance activities implemented on an individual ELV mission. The relative assurance roles and responsibilities of the ELV Program and the KSC SMA organization have not been defined (see R2). Current ELV flight assurance staffing is not adequate to provide credible insight into the current ELV workload consisting of approximately 30 to 40 vehicles in-flow and 10 to 15 launches per year. A MAM may reasonably be assigned to several different missions.

Develop Working Level Implementation Plans For Critical ELV Processes

Establish an individual Mission Assurance Manager for each mission

Mission Assurance (A) Processes (cont.)

	Responsible for Action	Recommended Action	Reference Observations
A3	**KSC/SMA**	Establish formal policy/processes and necessary resources to verify (on a set schedule) the implementation of contractor's mission assurance processes. ***Routinely audit contractor implementation of assurance processes***	According to interviews, "No one verifies implementation of contractor processes." The principle SMA function and responsibility with respect to both the core vehicle and mission-unique hardware/software is one of verification of the contractor's implementation of contract requirements set forth in the System Effectiveness Plan (SEP) and the Performance Assurance Implementation Plan (PAIP). All indications are that accomplishment of this function is being severely hampered by inadequate staffing, both in terms of total numbers available and appropriate balance and skill mix among safety, quality assurance, and flight assurance personnel (see R1). NASA should establish and maintain greater visibility into internal contractor assurance processes. One option is to formally participate in or observe contractor ISO (internal) audits. Another option is to conduct separate NASA audits in accordance with contract Program Surveillance Plan (PSP) provisions. The NASA Engineering and Quality Audit (NEQA) format represents a proven approach for verifying critical process fidelity and implementation.

Mission Assurance (A) Processes (cont.)

	Responsible for Action	Recommended Action	Reference Observations
A4	**KSC/SMA** HQ/OSMA	Develop and implement a documented process for SMA participation in the ELV CoFR process. Notes: The NASA HQ/OSMA letter of delegation for the Certificate of Flight Readiness is another area where improvement in Headquarters guidance is required. The basis of understanding and knowledge necessary to support the SMA CoFR signature is undefined and has been, until recently, based on limited knowledge of a very few lower level managers. ***Establish and document an SMA CoFR data package/decision process***	It is expected that the SMA signature will verify implementation of assurance activities in design, engineering, verification, and test of NASA mission-unique hardware and software, as well as satisfactory deployment of manufacturing and production assurance processes related to the preparation of the launch vehicle. It is also anticipated that the SMA signature will verify that prime and subcontractors have implemented and deployed the SMA requirements contained in contractor Systems Effectiveness Plans, Performance Assurance Implementation Plans, Risk Management Plans, Systems Safety Plans, and Quality Assurance Plans.
A5	**KSC/SMA**	Strengthen (stabilize) the KSC/SMA/ELV organization by filling vacant management and engineering positions at the Center and in the field. ***Fill acting positions in SMA/ELV organization***	As of the date of this report, the ELV SMA organization has operated for 8 months (11 months in the case of flight assurance), with no clearly defined leadership or chain of command. If indeed critical, KSC should fill the flight assurance position at Pueblo, Colorado.

Mission Assurance (A) Processes (cont.)

	Responsible for Action	Recommended Action	Reference Observations
A6	**KSC/SMA** KSC/ELV Program	Identify, commit, and implement a plan that addresses personnel support requirements at the contractors' plants. ***Stabilize SMA/ELV management of in-plant, contractor flight assurance support.***	KSC SMA needs to commit to, and initiate, a plan for procuring and maintaining support contractors. Much discussion about SMA support contractor procurement has been ongoing but, as of the time of this report, KSC is no closer to a decision. The existing ELV flight assurance support contractors have valid concerns about their future employment. KSC recently lost one excellent flight assurance engineer due, in part, to this uncertainty.
A7	**KSC/SMA** KSC/ELV Program	Consolidate management of DCMC delegated assurance functions performed in ELV manufacturing facilities. ***KSC/SMA should consolidate and provide overall management of DCMC activities.*** Note: DCMC does not support either Pegasus or Taurus manufacturing activities at Chandler, Arizona.	KSC/SMA needs to develop a consistent set of assurance functions and activities to be performed by DCMC as part of an integrated ELV assurance strategy. There was a strong sense that on any particular vehicle it is not obvious what assurance activities have been conducted by DCMC. Separate Letter's of Delegation (LOD's) exist for various facilities with differing assignments. In the case of LM-Denver the LOD is actually issued by the USAF and no one interviewed had a strong sense of what assurance activities are actually being implemented on a NASA vehicle. The review team examined the DCMC monthly report for the LM-Denver Atlas production facility and found the document to be of little use in understanding what assurance activities are being implemented and what the critical process health may be. KSC/SMA recognizes the apparent fragmentation and is beginning to audit and review DCMC costs and assurance process implementation.

2.2.4 Rationale for Assigning Recommendations to Specific Organizations

NASA Chief Engineer

The review team recommends that the NASA Chief Engineer assist in defining the depth of insight and independent analysis activities by establishing an ELV risk management forum to define the scope of assurance activities for individual missions, similar to the categorizations employed in the NMI 8610.7, "Procurement Risk Strategy."

NASA Headquarters Office of Space Flight

The Office of Space Flight (OSF) must move to clarify ambiguities regarding depth and breath of insight activities for core vehicle hardware and software and the mission-to-mission implementation of independent analysis assurance activities.

NASA's past success rate was built upon a foundation of workforce stability and experience including vehicle design, development, test, and operation. The GSFC and GRC ELV workforce understood how to interpret the requirements of NMI 8610.23. The KSC ELV Program is still evolving and developing as an organization and needs assistance in interpreting the high level guidance of NMI 8610.23, balancing implementation with increased workload and management expectations for mission success. OSF must also realistically assess the resource requirements necessary to operate a viable, consolidated, ELV Program Office (and supporting SMA organization) and most importantly, must provide the funding and staffing necessary for implementation. Finally OSF must work with OSMA, the Chief Engineer, and ELV customers to establish an ELV mission risk acceptance policy.

NASA Headquarters Office of Safety and Mission Assurance

Notwithstanding the current string of NASA ELV launch successes, continued success depends on NASA management moving with deliberate purpose to address current ELV management issues. The Headquarters Office of Safety and Mission Assurance must start this process by developing a top level ELV assurance requirement document and perform SMA functional audits necessary to assure that a robust ELV assurance capability is indeed implemented at KSC.

Kennedy Space Center

An excellent cadre of people with ELV experience has been recruited from within KSC as well as from GSFC and GRC. The "best of the best" approach, integrating the three engineering cultural norms, represents a good approach. However, the transition and staffing in all skill areas remains a work in progress. The review team recognizes many ELV Program strengths including the Mission Integration Team approach, the Engineering Review Board, the Mission Analysis and independent verification and validation capability, and the presence of engineering representatives in ELV manufacturing facilities. Equally dedicated staff in the SMA office are working hard to establish an ELV assurance organization that can provide a strong independent assurance capability. SMA is building on a small cadre of experienced field-based flight assurance managers and a nucleus of experienced ELV quality assurance technicians.

KSC top-level management has issues to address as well, including clarifying ELV assurance roles and responsibilities, flowing down Headquarters policies into Kennedy Documented Processes and ensuring that resources (staffing and contractor dollars) are allocated to enable ELV Program and SMA/ELV organizations. The ELV Program must move aggressively to identify and document critical engineering and assurance processes. The ELV Program must also define resource needs and act aggressively to fill vacancies in critical skill areas.

The KSC/SMA organization must move to address and embrace the ELV assurance responsibility. An integrated ELV assurance implementation plan must be developed and resources must be allocated to assure a reinforced flight assurance presence in manufacturing facilities with the intent of verifying, on an ongoing basis, that critical contractor assurance processes are implemented. Finally, the SMA participation in ELV Certificate of Flight Readiness processes must be formally documented and supported by demonstrated knowledge and understanding of assurance process implementation.

3.0 ELV Failure Case Studies and Gap Analysis

3.1 Background

Introduction

The NASA launch success rate (46 success in the past 47 missions: 97.9%) represents the assurance management heritage of GSFC and GRC (each center representing 30+ years of ELV management experience). The transition of ELV management to KSC represents a significant change in staffing and experience coinciding with an increase in manifest workload. With the transition to KSC are NASA's ELV assurance planning and processes adequate to maintain it's past level of success?

Assurance processes and culture formed over a thirty year period have establish the NASA template for ELV mission success. Discussions with experienced GRC and GSFC ELV managers concerning past success have identified the key factors shown below:

GSFC - GRC Historical Success Factors	KSC ELV	Short-Term Coverage
Cooperative teaming relationships with ELV suppliers	**Evolving**	NASA in-plant engineering personnel provide transition support. KSC-based engineering developing relationships
ELV Civil Service workforce experience	**Less experience** in ELV design and engineering areas	Continuing support from GSFC and GRC
In-depth government ELV Flight Assurance and Quality Engineering support	**Major gap** Needs Management (OSF and OSMA) attention (resources, roles and responsibilities)	Contractors (through GSFC and GRC) providing limited in-plant coverage
Government ELV team esprit d'corp	**Vulnerable** to burn-out given work load and current staffing levels	Workforce continuing "heroic" work pace
Embedded, institutional center support infrastructure (e.g., engineering, material laboratory, parts analysis, etc.)	**Not present** at KSC	Continuing support from GSFC and GRC

Review Team Evaluation Process

The probable cause of each failure was derived from recent mishap reports (available in current aerospace literature) or Aerospace Corporation Report No. TOR-97(8504)-3, May 1997, "Failure Study for Space Launch Vehicles (1983-1996) ."

The review team performed an independent evaluation to assess whether or not current KSC ELV assurance processes would have detected and prevented each specific mishap from occurring. The review team accepted the identified probable cause, in each case, as being correct. The team assigned a high, medium or low likelihood based on current KSC ELV and KSC SMA assurance processes, experience, knowledge, staffing levels , and work load.

It should be noted that the review team fully appreciates the very subjective nature of the assessments made herein. In fact, one of the purposes of conducting this gap analysis was to stimulate thinking and discussion regarding the adequacy of current ELV mission assurance processes. Hence, the review team invites the ELV program management at Headquarters and KSC to undertake their own analysis as a means to gain further insight and understanding of current mission assurance processes and to quickly focus on areas requiring improvement.

3.2 Probable Causes and Assurance Process Gap Analysis

ELV Failure Case Studies and Gap Analysis

	ELV Failure Description	General Comments	NASA ELV Assurance Process Or Activity That May Have Prevented This Mishap	Subjective Assessment High/Medium/Low Probability of Mishap Prevention
1.	**Delta II: 13 Jan 97-Booster Failure** Damage or flaw in the Graphite Epoxy Motor case. Undetected during pre-launch testing.	Manufacturing flaws or latent defects difficult to uncover if missed by contractor. In-plant NASA representatives participate in hardware pedigree reviews.	NASA/ELV Mfg. verification processes, i.e., pedigree reviews, build reviews, and test data reviews not likely to have detected a flaw in a motor case.	Low
2.	**Titan IV-A20: 12 Aug 98-Booster Cable Short** Intermittent shorts on vehicle power bus. Harness insulation was flawed prior to launch and escaped detection during preflight inspections.	Fundamental design issue or poor quality workmanship on just this vehicle.	NASA/ELV Design Verification and/or Mfg. Verification Activities would not likely have detected these failures. DCMC would be most likely to detect the potential failure mode. DCMC supports both NASA and DOD.	Low
3.	**Delta III: 26 Aug 98-Booster Failure** Human error in assumptions regarding applicability of Delta II software on the Delta III vehicle.	Used Delta II software on a Delta III, i.e. wrong application of software. Delta II control software assumed 4 Hz structural vibration modes would be damped (converging toward zero). Classic “heritage trap”.	NASA/ELV mission analysis group looks closely at changes to core vehicle software.	Medium

	ELV Failure Description	General Comments	NASA ELV Assurance Process Or Activity That May Have Prevented This Mishap	Subjective Assessment High/Medium/Low Probability of Mishap Prevention
4.	**Titan IV-B27: 9 Apr 99-IUS Failure (DoD)** IUS failed to separate properly. Electrical connector in the separation system failed to disengage. Poorly defined work procedure (involving thermal insulation and tape wrap) identified as root cause.	NASA operational pre-launch/launch review processes are in place. Launch site NASA presence at KSC is an added plus.	NASA/ELV Pre-Flight Verification & Test processes incorporate "Walkdown" activities which may or may not have found the error.	Low/Medium
5.	**Athena: 27 Apr 99-Booster Fairing Failure** Shroud failed to separate. Shock unplugged electrical connection. Electrical signal not received.	Greater than anticipated shock associated with initial fairing separation resulted in incomplete final separation. Apparently a design defect - design verification and test failure. Coupled loads analyses should have fully characterized the separation event.	If the vehicle was qualified under NPD 8610.7 then KSC Engineering would not likely have required special fairing/separation qualification testing which might have detected the problem.	Low/Medium

	ELV Failure Description	General Comments	NASA ELV Assurance Process Or Activity That May Have Prevented This Mishap	Subjective Assessment High/Medium/Low Probability of Mishap Prevention
6.	**Titan IV-B32: 30 Apr 99- Upper Stage Centaur Software Failure (DoD)** Incorrect flight constant was manually entered into the Centaur software. Human error.	Centaur flight software verification failure. Software experts consulted at GRC do not believe that KSC or GRC would have detected the coding error. One lessons learned, identified by GRC in the failure review, is to have the controls team evaluate the frequency response (Bode Plots) of "implemented software" to verify proper performance.	It is not likely that the NASA/ELV mission analysis group working with LMA would have detected this failure mode. The LMA controls group verified the filter constants (through simulation) but the constant was coded improperly (manual entry) by the software group. The FAST simulation does not exercise the Inertial Measurement System (IMS) software where the error occurred.	Low

	ELV Failure Description	General Comments	NASA ELV Assurance Process Or Activity That May Have Prevented This Mishap	Subjective Assessment High/Medium/Low Probability of Mishap Prevention
7.	**Delta III: 4 May 99- RL-10B Failure (DoD)** New manufacturing process (engine brazing process) coupled with higher than expected flight loads may have caused the rupture of the combustion chamber.	New (improved) inspection and NDE requirements have been imposed (ultrasound and x-ray) as corrective actions. New manufacturing process changes receive active scrutiny from KSC/ELV program management.	NASA/ELV design verification and/or manufacturing verification assurance activities may or may not have insisted on rigorous manufacturing process qualification and certification for a second tier supplier (P&W).	Low/Medium
8.	**Atlas-Centaur (AC-62): 09 Jun 84-Upper-Stage Failed To Boost (NASA)** Leak occurred in the LO2 tank. Incorrect clearance between inter-stage adapter and tank. High pressure in tanks at separation.	Failure difficult to mitigate through insight processes.	NASA GRC managed pre-commercial assurance approaches employed at this time. Very unlikely that diminished "insight role" would have detected.	Low
9.	**Titan 34D (D-7): 28 Aug 85-1st Stage Engine Shut Down (DoD)** Large oxidizer and fuel leaks and turbopump assembly failure.	Three separate and independent failures. Corrective actions were design changes and manufacturing processes.	NASA/ELV design verification and mfg. verifications not likely to have prevented this launch failure.	Low
10.	**Delta 178: 03 May 86-1st Stage Shut Down (NASA)** Electrical short in electrical relay box. Lack of redundancy, added relays, and second 28-volt power source.	Corrective actions were primarily design changes.	Failure occurred under GSFC (NASA oversight mode of operation). Current NASA/ELV design verification processes not likely to find flaws.	Low

	ELV Failure Description	General Comments	NASA ELV Assurance Process Or Activity That May Have Prevented This Mishap	Subjective Assessment High/Medium/Low Probability of Mishap Prevention
11.	**Titan 34D (D-9): 18 Apr 86-SRM Failure (DoD)** Motor case insulation unbonded in one of the vehicle's two SRMs. Hardware quality control need to be tightened.	Poor manufacturing process stability and control.	Current NASA/ELV manufacturing verification (in-factory quality) processes (DCMC) used the same people used by USAF.	Low
12.	**Atlas-Centaur (AC-67): 26 Mar 87 (NASA)**. Vehicle was struck by lightning. Electrical transient cause erroneous yaw maneuver and loss of vehicle control.	Presently NASA maintains conservative conditions for such a launch. Still, failure occurred under NASA processes.	NASA/KSC and USAF CCAFS have established weather rules and constraints which would prevent a re-occurrence of this mishap.	High
13.	**Titan 34D (D-3): 02 Sep 88-Transtage Failed To Re-Ignite (DoD)** Fuel tank and pressurization lines damaged from repairs or shrapnel impact during pre-launch activities.	One of two causes. Corrective actions included requiring validation and approval of repair procedures. Also cited was improved manufacturing and parts control.	NASA/KSC pre-flight testing assurance processes may or may not have required contractor to show data validating his repair process.	Low
14.	**Titan III (CT-2): 14 Mar 90-Intelsat VI Failed To Separate From 2nd Stage** Wiring team mis-wired the harness. The satellite never received the separation signal.	Commercial Titan generic composite system test (CST) failed to detect mis-wired configuration.	NASA/KSC pre-flight testing would require use of a spacecraft specific test protocol and would likely have found this error.	Medium

	ELV Failure Description	General Comments	NASA ELV Assurance Process Or Activity That May Have Prevented This Mishap	Subjective Assessment High/Medium/Low Probability of Mishap Prevention
15.	**Atlas-Centaur (AC-70): 18 Apr 91-One Centaur Engine Did Not Achieve Full Thrust** Air ingested into the turbo-pump liquefied and froze in the C-1 engine LH_2 pump and gearbox.	Failure difficult to detect by any secondary insight process. Design and new inspection/procedural corrective actions. New inspections and procedural changes were identified to eliminate debris in the fuel line.	NASA/ELV design engineering processes would have looked closely at a design change. Non-design change failure mode (latent defect) in design would not likely have been detected.	Low
16.	**Pegasus (F-2): 17 Jul 91-Incomplete 1st/2nd Stage Separation** Increased linear shaped charge, added spacer to protect charge detonation block. Fairing hinges strength increase and weather seal redesigned.	Design deficiencies. Low probability to detect failure.	NASA/ELV design engineering and design verification processes may (or may not) have identified failings in a new/modified design launch vehicle.	Low/Medium
17.	**Atlas-Centaur (AC-71): 22 Aug 92** Centaur C-1 engine failed due to the ingestion of air into the turbo-pump.	Difficult failure scenario to detect. Design and new inspection/procedural corrective actions.	NASA/ELV ERB would have carefully considered return to flight rationale, although a latent design defect would not likely have been detected by NASA/ELV engineering activities.	Low/Medium
18.	**Atlas-Centaur (AC-74): 25 Mar 93-1st Stage Thrust Loss** Regulator problem. Inefficient burning of fuel at lower throttle setting used up propellant.	Corrective actions were design changes (regulator redesigned) in a mature launch vehicle (latent defect).	NASA/ELV design engineering processes would have looked closely at a design change. Non-design change failure mode (latent defect) in design would not likely have been detected.	Low

	ELV Failure Description	General Comments	NASA ELV Assurance Process Or Activity That May Have Prevented This Mishap	Subjective Assessment High/Medium/Low Probability of Mishap Prevention
19.	**Titan IV (K-11): 02 Aug 93-Solid Rocket Motor Exploded** Propellant cut during restrictor repair. The repair was more extensive than had ever been attempted on such a motor segment.	Repairs to safety of flight items are reviewed by NASA representatives. While KSC ELV engineering does not have a solid rocket motor expert they may have sought support from MSFC.	NASA/ELV manufacturing engineering and flight assurance in-plant personnel working with KSC/Engineering may have disallowed use of the segment.	Medium
20.	**Pegasus XL (STEP-1): 27 Jun 94-Inaccurate Estimation Of The Vehicle Aerodynamics**. Erroneous aerodynamic predictions were used to design the flight control autopilot system. Insufficient design verification testing.	Too great a dependence on analysis and modeling coupled with marginal validation of model are root causes.	For first-time vehicle use or newly qualified vehicles there is a greater likelihood that KSC ELV engineering would detect this design defect.	Medium
21.	**Pegasus XL (Step-3): 22 Jun 95-2nd Stage Nozzle Was Confined And Could Not Gimbal Properly** Incorrectly installed skid imparted side force on interstage ring. Ring restricted movement of nozzle. Configuration control practices improved.	Manufacturing assembly errors within Orbital processes.	NASA/ELV manufacturing assurance activities would not likely have been able to detect these errors.	Low
22.	**Delta 228 (Koreasat-1): 05 Aug 95-One of nine SRM's Did Not Separate** Malfunction in the separation explosive transfer system. Overheated thin layer explosive transfer lines.	Separation system design changes (4 items) identified as corrective actions.	NASA/ELV design and engineering processes would not likely have identified these failure modes.	Low

	ELV Failure Description	General Comments	NASA ELV Assurance Process Or Activity That May Have Prevented This Mishap	Subjective Assessment High/Medium/Low Probability of Mishap Prevention
23.	**LMLV-1 (DLV): 15 Aug 95-Thrust Vector Actuation Mechanism Malfunctioned** Erroneous feedback signal caused by reduction of electrical resistance in cables. Cables heated by hydraulic oil ignition. Redesigned hydraulic oil expulsion, improved thermal protection for cables and TVA components.	Three fundamental design failures contributed to vehicle loss. Improper design verification testing is a contributing factor.	NASA/ELV design and engineering processes would not likely have identified these failure modes in a commercial launch mode. If qualifying vehicle for first flight it is possible that NASA would have identified design problems.	Low/medium
24.	**Conestoga 1620: 23 Oct 95-Unintended Thrust Vector Actuation Signal Was Sent To The Castor IVB Nozzle Actuator** No software filters to reduce noise to the onboard navigation computer.	Fundamental design flaws in hydraulics, software, and vehicle modal analysis. Latent design defects. If first flight or qualification flight NASA MSFC (in support of KSC engineering) may have detected design defects.	NASA design/engineering may or may not have identified failure modes in initial vehicle qualification. Post initial qualification NASA would not have been in a mode to capture a latent design defect.	Medium
25.	**Pegasus XL (HETE/SAC-B): 04 Nov 96-Shock Of Stage 2-To-3 Separation Induced Damage To Transient Battery (TB)** Corrective action calls for a new TB assembly procedure to include quality assurance verification and new inspection criteria.	This was a first time use of Pegasus dual-satellite capability. Pre-launch the battery was take apart, inspected and reassembled. An unknown failure mode within the battery was identified as the root cause.	NASA GSFC ELV engineering did not detect the failure mode. Even though KSC/ELV engineering focuses on first time use of new designs it is unlikely that KSC would have detected human error in assembly of the battery harness.	Low

3.3 Observations, Findings, and Recommendations

Background

Historically, U.S. ELV failures occur 5% of the time for the best operational vehicles. Potential loss-of-mission failure modes exist within many sub-systems within each ELV. The vast majority of vehicle designs are single string.

Using the clarity of hind-site it is usually easy to identify an existing process that might have or should have detected the failure mode. Most, if not all established ELV providers have fundamental engineering and management assurance processes in place. ELV failures are most often associated with:

- failed implementation of good processes
- inadequate design margins
- inadequate design verification

Human error and latent design flaws (marginal design) dominate most ELV failure scenarios for established ELV's. Examples include:

Human Error:

- Communication failure within a process
- Deviation from the process (breakdown of process discipline)
- Understanding of the process
- Lack of Experience

Design Defect

- Marginal designs
- Ineffective verification processes
- Invalid similarity assumption
- Insufficient analysis for Class II changes

Thus the most relevant questions to ask are related to process discipline, embedded process failure modes, and the extent to which both engineering and manufacturing processes are subject to attention by an outside party: oversight, insight or audit.

Finding

The review team does not believe the current level of NASA core vehicle insight will detect subtle errors in contractor execution of critical processes.

The team estimated:

- low likelihood of NASA assurance processes detecting latent design defects
- low likelihood of NASA assurance processes detecting a core vehicle manufacturing error. It should be noted that NASA insight into core vehicle manufacturing activities and insight into contractor assurance process implementation is, in general, minimal.

- medium to high likelihood that NASA assurance processes would have detected failure modes involving software misapplication or a failure in software configuration management (although it is not likely that these processes would have detected the April 30, 1999, Titan IV-B32 failure)

Human failure often occurs even within well documented processes. While human error is difficult to prevent, it can be mitigated when management makes a concerted effort and commitment to assure thorough process implementation and discipline.

Current NASA KSC assurance processes, especially in the commercial launch service acquisition environment, are not likely to stop specific human failure scenarios from unfolding.

<u>Opportunities Exist to Maintain Excellent Success Rate</u>

NASA ELV launch service contracts are structured to provide the NASA the opportunity to detect potential failure modes in design verification and test areas.

In order for the NASA KSC ELV organization to seize upon the contractually provided failure mitigation opportunities the workforce must be provided with:

- clear policy guidance (how deep and how wide) (recommendations P1, P3),
- clarification of roles and responsibilities, (recommendation R2),
- clear mission specific assurance expectations, (recommendation P2), and
- staffing, and contractor support, (recommendation R1).

Appendix A
Assurance Process Profiles

The ten element life-cycle assurance process model, as shown in figure 1.1, was simplified to eight elements to reflect the unique nature of the NASA launch service customer role. Detailed specific processes are described below:

A.1 Management Assurance Processes
A.2 Acquisition or Procurement Assurance Processes
A.3 Design and Engineering Assurance Processes
A.4 Design Verification and Test Assurance Processes
A.5 Software Verification and Test Assurance Processes
A.6 Manufacturing Verification and Test Assurance Processes
A.7 Operations Assurance Processes
A.8 Pre-Flight Verification and Test Assurance Processes

Note: The review team determined that assurance activities and processes (albeit often fragmented) exist in many of the major areas considered necessary for mission success. The team observed that several of the processes (e.g., Engineering Review Board, Mission Integration Team) can serve to manage risk in an effective manner. However, many other processes (e.g., integrated assurance planning, Flight Assurance roles and responsibilities, DCMC direction, core vehicle insight, NASA verification of contractor assurance process implementation, SMA Certificate of Flight Readiness participation) suffer from poor definition of roles and responsibilities, inadequate formal process documentation, and most importantly, a very thin implementation resource base, given the number of launch vehicles in-flow.

<u>Overview of KSC ELV Assurance Function Implementation</u>

The principal assurance functions are accomplished by a KSC ELV program workforce comprised of individuals who recently (within the past two years) transitioned from three strong and distinct NASA engineering cultures: KSC, GRC, and GSFC. The management objective is to identify the “best of the best” practices from each of the Centers and forge an organization that sets the standard for ELV engineering and customer support management. The consolidation is still a work in progress, with management focus on existing workload and recruiting over the past 18 months

When the ELV launch services activity transitioned to KSC, no new positions were created in the KSC SMA organization to support an ELV assurance role. The flight assurance representatives (GRC and GSFC heritage), combined with a small but dedicated ELV quality assurance team based at KSC, essentially provided a flight assurance bridge to the present. From October 1, 1998, to mid-April 1999 there was no KSC-based ELV flight assurance organization. Subsequently, three flight assurance managers have been assigned to support the ELV program at KSC. This is an issue which is discussed further in the findings and recommendations section of the report (section 2.2). The emerging KSC SMA role should include independent assessment of ELV Program and contractor process implementation, special emphasis on first flight and mission critical issues, continued in-plant flight assurance surveillance, monitoring and insight activities (paralleling guidance described in NASA STD 8709.2), and development of a more robust content-oriented, assurance knowledge-based SMA CoFR process.

Technical insight and oversight is accomplished through the combined efforts of in-plant resident office engineering representatives and flight assurance managers, KSC-based discipline (electrical, mechanical, etc.) engineers, and flight and quality assurance managers. The KSC staff is primarily responsible for the acquisition and management, technical integration, design, analysis, IV&V, launch site integration, and launch management of NASA launch services. Resident offices are maintained at contractor facilities and provide a fleet monitoring function along with focused involvement (approval and insight) with NASA designated hardware and software (core vehicle and mission-peculiar). Resident staff serves as the eyes and ears for the KSC-based engineering team and maintains awareness of problems in production, scheduling, parts, quality, and other factory-based issues.

Insight and approval for NASA missions is executed through a combination of civil service and support contractors. The largest portion of the support staff is located at KSC, with supporting resident offices at: Huntington Beach, California - Denver, Colorado - Chandler, Arizona - Pueblo, Colorado - and Vandenberg AFB, California.

The primary role of the resident offices at Huntington Beach, Denver, Chandler, Pueblo, and Vandenberg AFB is production, programmatic, and mission integration insight. The resident offices are staffed with a core contingent of civil servants with support contractors in critical disciplines. The resident offices are augmented by KSC engineering and mission assurance support during peak work periods and reviews.

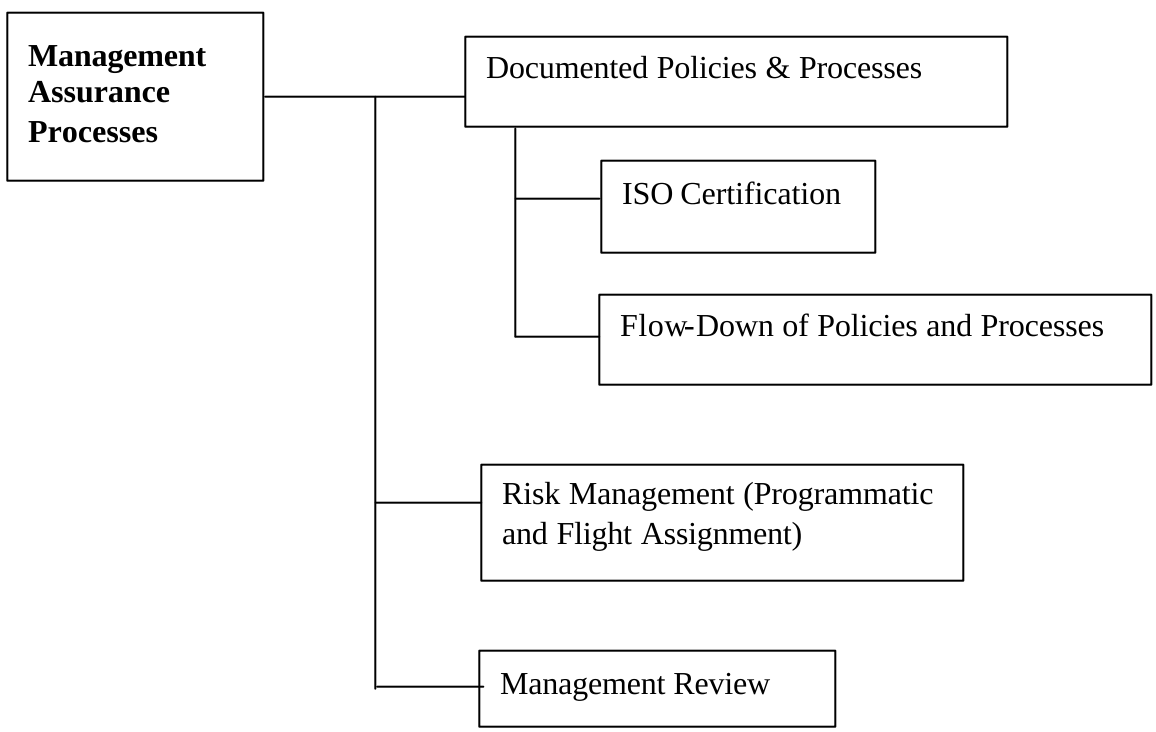
Notes on Structure and Flow of Sections A.1 through A.8

The objective in each of the sections A.1 through A.8 is to describe the assurance activities and processes implemented in each PBMA element. Examples from Atlas, Delta, Titan II and Titan IV missions are used to illustrate current (and immediate past) implementation of processes. The review team has not had the time or opportunity to adequately understand the scope of assurance process implementation on OSC ELV missions. It is our supposition that the emergent KSC/ELV culture will largely reflect "best of the best" GRC and GSFC practices. Current differences in assurance approach will likely diminish although some fundamental differences will always remain.

A.1 Management Assurance Processes

Introduction

A documented top level management commitment to mission assurance and risk management is a necessary first step in establishing management assurance processes, policies, procedures, and documented requirements. Other key concepts include development of an assurance management strategy and implementation of assurance plans including a formal risk management plan. Management risk control concepts include audits to verify program and contractor assurance process implementation, assurance control boards, independent assessment, and formal management assurance reviews. Complex risk management issues invariably benefit from an informed and knowledgeable second opinion. Independent assessments are also applicable to design, engineering, manufacturing, and operational activities.



Documented Assurance Policies and Processes

The NASA ELV management assurance processes include Headquarters policy directives, letters of delegation, memoranda of understanding, and NASA standards as outlined below. Each of these documents defines certain processes and activities designed to assist in maintaining safety, managing risk, and achieving a higher likelihood of mission success.

Office of Space Flight

NMI 8610.24, “NASA Pre-launch Review Process” - This Instruction establishes the ELV prelaunch review process necessary to assess and certify the readiness for launch of the launch vehicle including separately provided upper stages and supporting launch services provided by commercial companies or by the DoD.

NMI 8610.23, “NASA Technical Oversight Contract Requirements” – This instruction establishes NASA’s policy with regard to requirements for NASA to use ELV launch services provided by the private sector whenever available. NASA's accountability for success of its missions launched with private sector ELV launch services remains unchanged. Greater day-to-day oversight and insight responsibilities have shifted to the contractor. However NASA retains the responsibility and authority to direct technical changes it deems necessary.

NPD 8610.7, “NASA Procurement Risk Strategy” – This document establishes NASA policy with regards to requirements for NASA that state launch services acquired for deployment of NASA-owned, NASA-sponsored payloads must take advantage of all reasonable sources of U.S. commercial launch services, and at the same time, ensure that taxpayer-funded spacecraft are not thereby exposed to excessive risk. NASA launch services acquisition strategy balances mission risk with launch vehicle demonstrated flight history and maturity.

Office of Safety and Mission Assurance

NASA STD 8709.2, “NASA Safety and Mission Assurance Roles and Responsibilities for ELV Services” – This document defines the NASA Safety and Mission Assurance roles and responsibilities as they apply to the various commercial launch service procurement methodologies. The document addresses the NASA SMA functions required for each mission phase from procurement through design, production, launch vehicle integration, spacecraft integration, system test, pre-launch operations, launch operations, post launch activities, and mishap investigations.

NASA STD 8719.8, “NASA ELV Payload Safety Review Process Standard” – This document addresses the tasks, responsibilities, safety data package submittals, safety reviews/meetings, and schedules/milestones associated with the ELV payload safety review process. The safety review process for generic launch vehicle systems is outside the scope of this document and is defined by the applicable approving authority safety requirements document. The involvement of NASA Headquarters and NASA Field Installations is defined in NHB 1700.1, "NASA Safety Policy and Requirements Document." Payload safety design requirements are not covered in this document nor are environmental, biological, health physics, and flight safety approvals.

ISO 9001 Certification

NASA HQ/OSF - On June 2, 1999, NASA Headquarters was approved for ISO 9001 certification from an internationally recognized registrar, Det Norske Veritas (DNV), of Oslo, Norway, and Houston, Texas.

DNV conducted an audit of the NASA Headquarters quality system on May 21, 1999, and recommended Headquarters for ISO 9001 certification. The scope of the certification includes the Strategic Enterprises - Scientific Research, Space Exploration, and Technology Development and Transfer missions. OSF is included in this certification. Within OSF is the ISO certified ELV Manifest Process. This process is documented in HOWI8682-M012. The purpose of this process is to describe the steps that lead to the development of the manifest for NASA missions utilizing ELV's.

NASA HQ/OSMA - ISO 9001 certification of NASA Headquarters currently includes only the first of a two-phase effort. Phase II of HQ ISO 9001 implementation was recently approved by the Associate Deputy Administrator. In Phase II, all Functional/Staff Offices (FSO's), including OSMA, will be included in the scope, and a reassessment performed by DNV in May 2000. With the completion of Phase II, all Headquarters offices will be within the scope of HQ ISO 9001 certification.

Contractors - Boeing Delta facilities at Huntington Beach and Pueblo are certified to ISO 9001. The certifying agent is Det Norske Veritas (DNV).

LMA, Littleton, CO, was certified on December 13, 1996, by British Standards Institute (BMI), Inc., and NASA was involved in the ISO 9001 internal audits.

OSC, Chandler, AZ, was certified on July 8, 1998, by BMI, Inc., and NASA was involved in the ISO 9001 internal audits.

Coleman Aerospace, Orlando, FL, was certified on September 29, 1998, by NSF International Strategic Registration. NASA conducted a second party audit concurrent to the third party certification by NSF.

Flow-Down of Policies and Processes

KSC ELV Program - KSC employs a system of documentation developed to achieve compliance with the requirements of ISO 9001. These documents are referred to as Kennedy Documented Procedures (KDP's). The following KDP's, representing the portion that apply to the KSC ELV Program Office, were included within the scope of the initial ISO 9001 certification completed at KSC on May 15, 1998.

KDP-P-1099, “Expendable Launch Vehicle (ELV) Launch Management”
KDP-P-1067, “Expendable Launch Vehicle (ELV) Insight and Approval”
KDP-P-1081, “Ground Operations Review (GOR)”

KSC/SMA - A number of high-level SMA KDP’s, applicable to the ELV program, were included within the scope of the initial ISO 9001 certification completed at KSC on May 15, 1998. A partial listing is provided below:

KDP-P-2350, “Quality Assurance Program”
KDP-P-2351, “Quality System Assessment (QSA) Program”
KDP-P-2352, “Quality Assurance Surveillance Program”
KDP-P-2360, “Procurement Quality Division Documentation Review”
KDP-P-2361, “Procurement Quality Division Delegation of In-Plant Quality Assurance Functions”
KDP-P-2362, “Procurement Quality Division Delegated Agency Survey”
KDP-P-2363, “Procurement Quality Division Quality Audits”
KDP-P-2364, “Procurement Quality Division Pre-Award Survey”
KDP-P-2365, “Procurement Quality Division Contract Quality Assurance Management Files”

Risk Management - Programmatic

NASA Procedures and Guidelines (NPG)7120.5A requires that each: “program or project manager shall apply risk management principles as a decision making tool which enables programmatic and technical success. Program and project decisions shall be made on the basis of an orderly risk management effort, including the identification, assessment, mitigation, and disposition of risks throughout the program management process.” The ELV Launch Services Project Status forum uses a “stoplight” tracking approach to identify and track program risks. This forum, as described below, serves to address schedule, cost, and technical risks.

Green - The Management Integration Team (MIT) is operating on a “business as usual” approach; on schedule to meet launch date, on budget, and with no technical issues that will delay launch or exceed the budget.

Yellow - MIT is working issues that require management awareness and may require management action, including technical/budget/contract issues that could effect the scheduled launch date if not resolved in a timely manner. Solution or a path to the solution has been identified.

Red - MIT is stopped and requires management action; issue(s) with no solution or mitigation plan identified. Issue(s) could result in high risk to launch success or seriously impact launch schedule or mission budget.

An example of the ELV Program risk tracking approach is provided in the following chart.

Attention Missions Stoplight

MISSION	PAGE(S)	OVERALL RATING	CORE VEHICLE	MISSION INTEG.	SCHEDULE	LAUNCH SITE	LAUNCH SERVICE
GOES-L	8-9	R	R	G	R	G	G
EOS-AM TERRA	10-11	R	R	G	R	G	G
TDRS-H	12-13	G	Y	G	G	G	G
EO1/SAC-C	14-15	R	G	R	R	G	G
VCL	16-17	G	Y	G	G	G	Y
GP-B	18-19	G	G	G	Y	G	G
MSP '01 Lander	20-21	G	G	Y	G	G	G
ICESAT/CATSAT	22-23	Y	G	G	G	G	G
GOES-N	24-25	R	R	G	G	G	G

Figure A-1

Risk Management - Flight Assignment

The NASA Commercial Launch Services Acquisition Review conducted in 1995 and 1996 and led by the NASA Headquarters Chief Engineer resulted in the formal establishment of a launch services risk mitigation policy (NPD 8610.7) for NASA-owned or NASA-sponsored payloads.

This policy directive defines the process to assess mission risk based on vehicle maturity and demonstrated flight history. Three categories of risk have been established:

- Category 1: Payloads deemed non-mission critical can be considered for flight on vehicles with no flight history.

- Category 2: Payloads deemed mission critical to Enterprise Strategic Plans and of moderate cost/complexity can be flown on NASA-acquired services with at least one demonstrated flight.

- Category 3: Payloads deemed mission critical with complex interface and higher cost can be flown on vehicles with demonstrated flight history, i.e., 14 or more consecutive successful flights.

NPD 8610.7 also requires that all NASA payloads will be flown on U.S. vehicles unless a Presidential waiver is granted. In addition, any international cooperative activities need to utilize a similar risk assessment process when foreign launch services are being considered. On-orbit services from qualified suppliers will be evaluated on a case-by-case basis with the OSF and the appropriate payload Enterprise.

Management Review Forums

The ELV program employs numerous management review forums within the general categories outlined below.

Periodic Senior Management Reviews -

- Quarterly Program Reviews
- Monthly Status Report (ELV and Spacecraft Project Report)
- Weekly Project Status (ELV Program Internal)

Engineering and Integration Reviews -

- Mission Integration Working Groups (MIWG's)
- Engineering Review Boards
- Preliminary/Critical Design Reviews
- In-plant Product Reviews
- Design Certification Reviews.
- Technical Interchange Meetings
- Engineering Review Boards
- Systems Requirements Reviews
- Preliminary Design Reviews
- Critical Design Reviews
- Vehicle Engineering Review Boards
- Vehicle Software Reviews
- Vehicle Test Readiness Reviews
- Vehicle Build Reviews

Launch Readiness Reviews - NPD 8610.24 requires the following readiness reviews prior to commitment to launch

- Spacecraft Mission Readiness Review

- KSC Center Director's Launch Vehicle Readiness Review

- Launch Readiness Review at launch minus one day (L-1)

- Final Poll for Launch

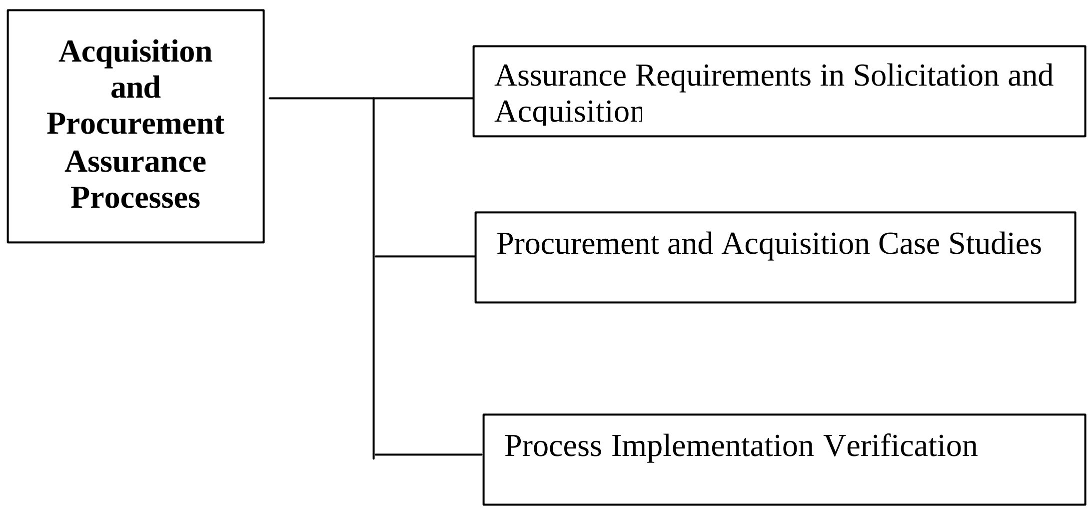
In addition, KSC conducts a Flight Readiness Review (approximately L-4) which is performed prior to the initiation of the final preparations for launch.

These reviews include the description of the launch service, mission-unique items, first flight items, and anomaly closures from previous missions. At the conclusion of these meetings a poll is conducted to assure that all parties responsible for mission success agree with proceeding to the next milestone.

A.2 Acquisition and Procurement Assurance Processes

Introduction

Key acquisition and procurement processes include the Source Evaluation Board (SEB) activities in which necessary assurance provisions are included in the contract notwithstanding the barriers imposed by changing legislative direction. The SEB has the power to establish the assurance requirements as described below:



If a contractor is selected who has proposed to implement demonstrated and capable assurance processes, the pre-award audit serves to verify process implementation and capability. Subsequent periodic audit of contractors will serve to validate, on an ongoing basis, the implementation of critical assurance processes. Finally, the assignment of payloads to launch vehicle based on demonstrated performance represents yet another assurance process.

Background

Commercial Space Launch Act Amendment of January 1998 - Under the provisions of the FAR Part 12 procurement, launch services must now be procured as commercial items. This mandates that the government must accept those processes and documentation that are customarily provided by or are consistent with accepted commercial launch service industry practices. Thus, this procurement approach limits the government's insight into the launch service provider's design and development processes and restricts the ability to set forth or impose specific mission assurance requirements. Any mission assurance oversight or approval requirements that the government might wish to impose, and that are not consistent with said commercial practices, require a specific waiver and supporting justification.

FAR Part 12 limits the detail and amount of pricing data available to the government because this information is associated with the company's competitive position relative to current and future contracts and is, thus, considered to be proprietary in nature. The pending NASA Launch Service (NLS) contract will be the first launch service procurement using FAR Part 12.

All current commercial launch service contracts incorporate FAR Part 15 procurement requirements. Under FAR Part 15 the government has the authority and, indeed, the responsibility to impose any and all requirements (processes, practices, documentation, etc.) it deems necessary to assure success for its missions.

Existing KSC ELV Launch Service Contracts - NAS5-30722 with McDonnell Douglas (Boeing Corporation) for Medium Class ELV's (MELVS) was previously managed at GSFC. This contract was awarded on November 14, 1990, with three firm missions and 12 options. All of those options have been exercised with a modification to exercise the last two options for Mars '01 Orbiter mission and the SIRTF mission. This modification was executed on September 30, 1998. The total estimated price of the contract at this time is $775M. There are no remaining options after execution of the contract modification.

NAS5-32933 with McDonnell Douglas (Boeing Corporation) for Med-Lite (Medium-Lite) ELV's was previously managed at GSFC. This contract was awarded on February 27, 1996, with five firm missions and nine options. Four of those options have been exercised with five remaining. The total estimated price of the contract at this time is $367M. There are planned missions on the manifest to cover options through 2002.

NAS5-32836 with Orbital Sciences Corporation for UELV's was previously managed at GSFC. This contract was awarded on December 23, 1994, with two firm missions and eight options. One of those options was exercised (CLIN #3). This mission was for HETE-11/ACRIM that was scheduled for October 1999. However, a stop-work order was issued in September 1998, for CLIN #3 to move ACRIM to another launch vehicle. The total estimated price of the contract at this time is $24M. The last date for exercising the remaining options is December 22, 1999.

NAS3-27262 with Lockheed Martin for IELV launch services was previously managed at GRC. This contract was awarded in December 1994. One firm mission and eight options (TDRS-H/I/J) have been exercised to date. There are five remaining options that can be exercised through December 2000. The total contract value to date is $400M.

NAS3-23440 with Lockheed Martin for GOES was previously managed by GRC. This contract was awarded May 20, 1988. It encompassed the GOES I-M launches. The contract had three firm missions with two options. Both options (GOES L and M) were exercised. The launches are planned for FY 1999 and FY 2001, respectively. The total price of the contract at this time is $375M.

Contract NAS10-99005 with Orbital Sciences Corporation and NAS10-99010 with Coleman Aerospace were awarded in October 1998: This procurement and the resulting contracts are being managed by KSC. The launch service being procured is a multiple award, indefinite deliver/indefinite quantity (ID/IQ) contract that will support up to 16 launch services with an ordering period of 5 years.

Future KSC ELV Launch Service Contracts - The NASA Launch Services (NLS) contract is in the procurement stage. The draft Statement of Work (SOW) was released in March 1999, and a draft RFP was released in April 1999. The proposed contract represents NASA's requirements for domestic launch services with a minimum performance capability of placing a 1,500-kilogram spacecraft in a 200-kilometer orbit at an inclination of 28.5 degrees. This procurement will seek to adopt the best commercial practices and customs while ensuring Agency mission needs are satisfied via safe and reliable access to space. The procurement envisions a multiple year period of performance beginning at contract award tentatively scheduled for fourth quarter CY 1999.

Assurance Requirements in Solicitation and Acquisition

NASA Management Instruction (NMI) 8610.23 establishes "Technical Oversight of Expendable Launch Vehicle Services." Oversight, as defined in NMI 8610.23, means government approval and insight. NASA's program approval refers to providing the launch service contractor authority to proceed and/or formal acceptance of requirements, plans, tests, or success criteria in specified areas. NASA's program insight refers to the Agency gaining an understanding necessary to concur/nonconcur with contractor actions through watchful observation, documentation, meeting attendance, reviews, tests, and compliance evaluations. The NMI applies to NASA Headquarters and all NASA Centers, and affects all ELV service contracts. NASA program launches established through grants are not subject to Agency technical oversight.

NMI 8610.23 requires that when NASA acquires launch services, its solicitations and contracts will:

- Include the government's approval and insight requirements
- Permit independent verification/validation by NASA of selected critical mission analyses, processes, tests, and acceptance criteria to maximize probability of launch success
- Permit approval by NASA of all mission-unique analyses, spacecraft to launch vehicle interfaces, design, and test procedures
- Permit substantial involvement in, control of, and final approval by NASA of the go-for-launch
- Protect public health, safety, and property; adhere to national environmental guidelines; and preserve national security and foreign policy interests attendant with a government launch.

Procurement and Acquisition Case Studies

The NASA Launch Services (NLS) Procurement - The NLS contract is currently in the initial procurement stage. Under the provisions of the Commercial Space Launch Act - Amendment of January 1998, launch services are now to be procured as commercial items. This falls under FAR Part 12. During initial NLS acquisition meetings, it was determined that additional requirements were needed by NASA to assure an acceptable level of mission risk and to fulfill NASA assurance responsibilities.

FAR Part 12 allows waivers to permit specification of assurance requirements beyond those normally applied for basic commercial items. Waivers were requested by KSC and approved by NASA Headquarters in following areas:

- Inspection acceptance clause (addition of NMI 8610.7, NMI 8610.23, and NMI 8610.24 as requirements to the commercial procurement)
- Changes clause (addition of requirements that the government retains the ability to direct changes)
- Payment clause (addition of requirements that payments will be made based on progress/performance versus specified time periods).
- Insight (addition of requirements that NASA will have insight)

In addition, the NLS contract required ISO 9001 certification and plans for system safety and health, reliability, quality assurance, parts control, materials control, processes control, contamination control, electro-static discharge control, configuration management, and software control.

Acquisition Case Study – NASA Oversight: FUSE/Delta 7320 - The FUSE/Delta 7320 launch vehicle was acquired under the Med-Lite Launch Services Program, contract number NAS5-32933. In accordance with the Med-Lite SOW and related documentation requirements, Boeing has established a Performance Assurance Program as set forth in the Program Assurance Implementation Plan (PAIP). NASA requirements documents NHB 5300.4 (1A1) and NHB1700.1 (VI-B) and ANSI/ASQC Q9001 were used as overall guidance in the development of the Performance Assurance Program and PAIP. The objective of the PAIP is to ensure a high probability of mission success through the design, production, and operation of a safe, reliable, and high quality launch system. This objective will be accomplished through the following:

- Establishment of effective performance assurance management systems, policies, and controls
- Implementation and verification, through inspection and test, of safety and reliability design features
- Conduct of oversight analysis, inspection, and test verifications to ensure vehicle compliance with the intended design
- Flow down of performance assurance requirements consistent with system level requirements to subcontractors and implementation of vendor controls

- Conduct of periodic reviews and audits to verify that performance assurance requirements are being met.

The PAIP (as well as the System Effectiveness Plan) contain sections which address the following assurance areas:

- System Safety and Health
- Reliability
- Quality Assurance
- Parts, Materials, and Processes
- Contamination Control
- Electrostatic Discharge Control
- Configuration Management
- Software

Government monitoring of launch services provided by the private sector has two elements, approval and insight. Government approval is defined as providing authority to proceed and/or formal acceptance of requirements, plans, designs, analyses, tests, or success criteria in specified areas. Government insight is defined as gaining understanding necessary to knowledgeably concur with the contractor's action through watchful observation, inspection, or review of program events, documents, meetings, tests, audits, hardware, etc., without approval/disapproval authority. NASA has approval authority for activities related to spacecraft integration and mission analyses, integrated spacecraft/vehicle prelaunch operations, launch countdown procedures and launch go/no go decision. Insight responsibilities apply to launch vehicle system design, development, and production, vehicle integrated systems tests, launch site vehicle assembly and test, and post flight analysis. Specific approval and insight responsibilities for the FUSE/Delta II mission are delineated in the Med-Lite contract, Section H.3, and the PAIP.

Acquisition Case Study – Limited Oversight: QuikSCAT-Titan II (G7) - The case of Titan II and Principal Investigator (PI) acquisitions (acquisition in this case means providing NASA resources to acquire an ELV launch) is important to consider. It is not clear what NASA policy directives apply. There is no documented process which describes Memorandum of Agreement (MOA) interfaces, coordination, or the specification of assurance requirements for ELV's when provided by the Department of Defense.

The QuikSCAT-Titan II (G7) mission MOA with the U.S. Air Force, does not explicitly address SMA requirements. The MOA notes that NASA has mission success responsibilities but indicates that neither the USAF nor NASA will independently review or assess each other's hardware or software. NASA is therefore entirely dependent upon the USAF which has ultimate responsibility for launch vehicle systems. NASA has responsibilities for defining the overall mission requirements. The MOA was developed by the OSF. Signature blocks are provided only for the Associate Administrator for Space Flight and an Assistant Secretary of the USAF. The MOA did not involve any members of the NASA SMA community. The MOA did involve the NASA General Counsel late in development. Five days prior to launch, the MOA had not been signed by all parties.

Core vehicle assurance requirements were contained in existing contracts between the USAF and Lockheed-Martian Astronautics (LMA). Additional quality assurance requirements were contained in the USAF Letter of Delegation (LOD) to the Defense Logistics Agency (DLA) through an MOA. Spacecraft assurance requirements were defined in a GSFC LOD to the DLA resident at the Ball Aerospace facility in Boulder, Colorado. Range safety requirements are contained in Eastern Western Range (EWR)-127-1.

The USAF is responsible for implementing all launch vehicle assurance activities through their relationships with LMA, Aerospace Corporation, DLA, and the Vandenberg Air Force Base commander. GSFC is responsible for implementing assurance activities on the spacecraft through their relationships with DLA and Ball Aerospace.

NASA provided $2.4M in assurance support to the USAF to pay for Aerospace Corporation support. There was no NASA independent validation of LMA analyses although there was significant Aerospace Corporation independent validation activity in many areas including software, mission planning (trajectory), and coupled loads. NASA did review all LMA and Aerospace Corporation analyses.

The MOA language serves to minimize or limit NASA involvement in performing independent verification or validation of contractor mission critical engineering, test, or assurance activities. The MOA language paragraph 6 states, in part:

> *"None of these principles (embodied in the MOA) shall be construed as giving NASA basic responsibilities for the launch vehicle system …these remain with the Air Force."*
>
> *"…Both parties will assure that their participation is non-intrusive and in the spirit of acting as an informed partner. It is not intended or planned that NASA or the Air Force will perform an independent assessment of the other party's hardware/software."*

Individuals interviewed described the NASA insight as "arms length," "minimal coverage," and "restricted." Access of NASA SMA and engineering personnel to the vehicle on the pad was indeed restricted

<u>Process Implementation Verification</u>

A fundamental NASA mission assurance need is to verify that assurance activities defined in planning documents have indeed been implemented. Knowledge and understanding are derived from oversight (approval), insight (observation), witnessing, reviewing documentation and data, attendance at briefings and reviews, and independent analysis. Access to hardware, launch facilities, and documentation is required to perform effective verification and validation. Assurance processes are typically incorporated into the Systems Effectiveness Plans (SEP's) or equivalent documents as required by NMI

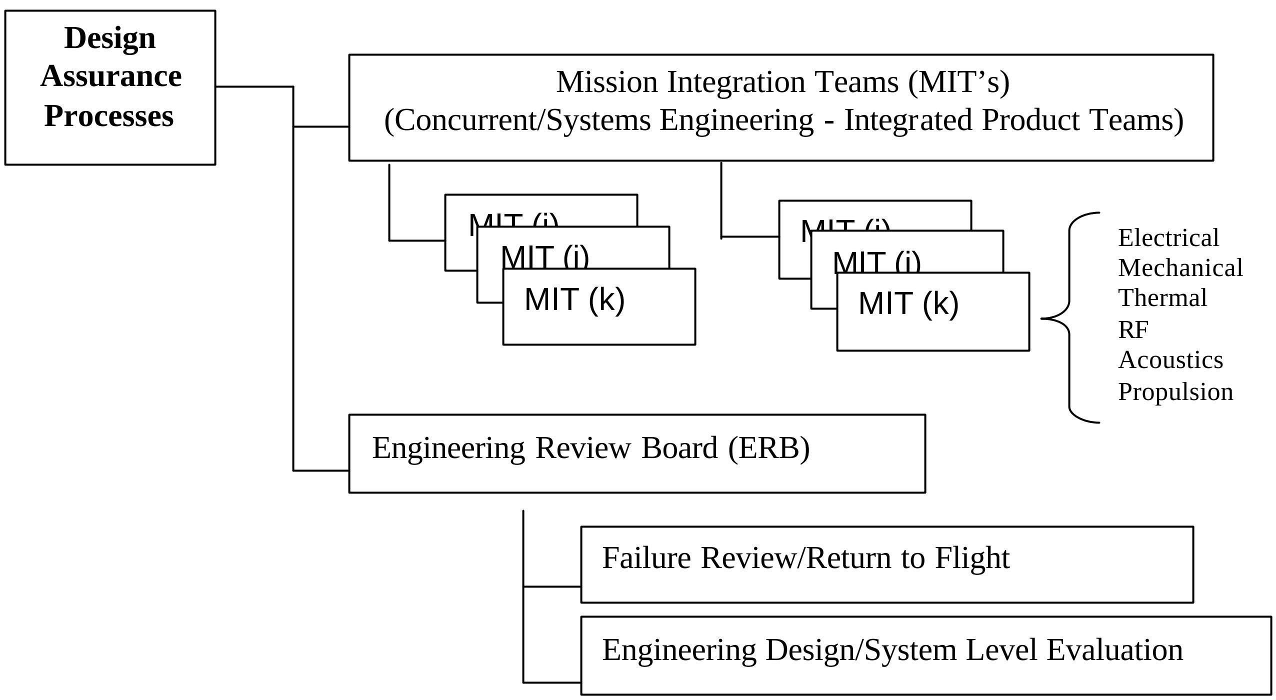
8610.23. The Boeing Product Assurance Implementation Plan (PAIP) serves as the key assurance document for the Med-Lite contract.

Future Contracts without SEP's - ELV contract assurance provisions are moving away from the SEP/PAIP approach toward ISO 9001 certification, providing confidence that a minimum, baseline quality management system is in place. NASA then imposes additional requirements above and beyond ISO 9001. Project Surveillance Plans will specifically delineate who has approval and insight responsibility for NASA requirements

A.3 Design and Engineering Assurance Processes

Introduction

Design and engineering assurance processes are considered those systems engineering disciplines and methods that tend to mitigate or control design risks. The NASA ELV Program office employs a concurrent engineering approach centered on the activities of the Mission Integration Teams and the Engineering Review Board. Neither process is yet formally documented with a KDP but both processes are well understood by participants and serve to achieve the benefits of a system level engineering perspective.



Mission Integration Team (MIT) Approach

Mission integration is the primary responsibility of the Mission Integration and Customer Division and is accomplished through the formation of MIT's (see figure A-2) which are established for each individual mission. The MIT serves as the link between the spacecraft customer and the launch vehicle service provider. The Mission Integration Manager (MIM) leads the MIT and is supported by an Integration Engineer, who provides discipline engineering, mission analysis, and mission assurance; a Launch Service Manager, who provides procurement and finance support; and a Launch Site Integration Manager, who is responsible for range and launch operations support. The MIT assumes total management of the mission integration process. The MIT becomes involved in the integration process very early by providing mission analysis and feasibility study support in the pre-Announcement of Opportunity (AO) and AO phases of mission selection. One team is established per mission with core team membership drawn from the ELV Program. The MIT, typically established 30 to 36 months prior to launch, serves as the principal customer point of contact and the launch services mission point of contact.

Once a mission receives Authority to Proceed (ATP), the MIT uses the following forums to refine mission requirements:

- Mission Integration Working Groups (MIWG's)

- Preliminary/Critical Design Reviews

- In-plant Product Reviews

- Design Certification Review

Integration and other issues are reported and tracked through:

- Weekly Project Status (ELV Program Internal)

- Monthly Status Report (ELV and Spacecraft Project Report)

- Quarterly Program Reviews

- Technical Interchange Meetings

- Readiness Reviews (NASA and contractor)

- Engineering Review Boards

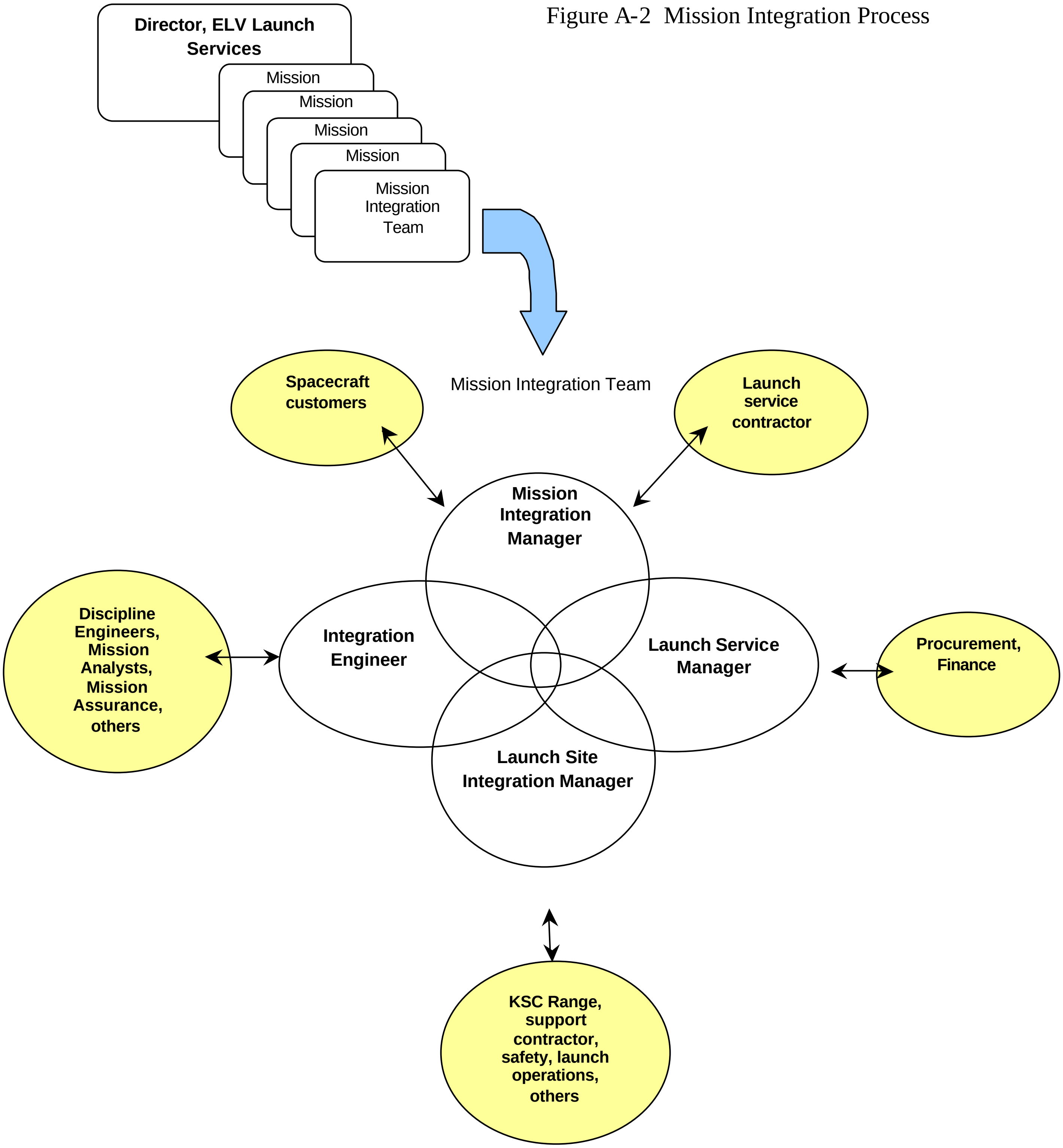
The process allows both the Government and the launch service provider the opportunity to work the closure of any issue through the Launch Readiness Review (L-1). If an issue cannot be closed prior to the start of the launch countdown, the ELV Launch Services Project will not consent to proceeding with the launch.

MIT Lessons Learned - The Mission Integration and Customer Division also employs an internal review, lessons learned/continuous improvement process. This process involves formally logging actions, identifying individuals to address those actions, and tracking closure of the actions. Typical ELV lessons learned include:

- issues which may have fallen through the cracks requiring additional oversight by management
- areas which could benefit from better coordination of MIT team activities
- areas where confusion may have existed
- areas requiring extra emphasis in MIWG’s preparation activities
- areas where improved communication is important
- issues associated with timing and schedule margin
- the need to develop a process or schedule
- the need to determine who is responsible and has authority to address closure of issues
- other “out-of-standard process” issues

The lessons learned forum also serves to identify strengths and positive outcomes from previous launch campaigns.

Figure A-2 Mission Integration Process



Engineering Review Board (ERB)

The ELV Launch Services Vehicle Engineering and Analysis Division employs an ERB as the principal technical engineering risk management forum. The independent ERB does not consider cost and schedule but seeks to identify the best technical course of action. An ERB is convened when a systems level evaluation is required for issues raised by any individual within the engineering or integration organizations. Throughout the mission integration process, engineers will identify and resolve problems through analysis, test, and technical interchange meetings. Typically two to three issues are identified each week as potential ERB candidates. The KSC/ELV ERB process derives from both the GRC and GSFC ELV Program management heritage. The ERB process, while routinely implemented, has not yet been formally documented (with a KDP) and is not incorporated under the KSC/ELV ISO 9001 certification.

Membership - The ERB is chaired by the Vehicle Engineering and Analysis Division Chief Engineer. The four other permanent ERB members are drawn from within the Vehicle Engineering and Analysis Division including:

- Chief, Vehicle Engineering and Analysis Division
- Chief, Mission Analysis Branch
- Chief, Mechanical Systems Branch, or Chief, Avionics & Electrical Branch
- Chief, Engineering Integration Branch, or Integration Engineer (Mission Specific)

Prior to April of 1999 there were no ELV/Flight Assurance Managers (FAM's) at KSC. It is the intent of the Chief Engineer to seek SMA/FAM participation in future ERB meetings. It is also important to note that contractors and other interested/contributing individuals and organizations may be invited to attend ERB discussions.

Criteria for Establishing an ERB – The informally implemented ERB start up criteria include:

- ELV launch service provider request for engineering evaluation
- Class-1 (form, fit, or function) changes to the core vehicle
- Changes in any aspect of core or mission-peculiar hardware or software
- In-flight anomaly and return-to-flight rationale development

Return to Flight Rationale – The ERB has a track record of exercising care and due diligence in evaluating and accepting contractor logic and rationale to support return-to-flight decisions after the occurrence of a mission failure. The fundamental engineering concept and NASA cultural norm of never flying with a known unknown serves as starting point for ERB deliberations. The ERB attempts to establish knowledge and understanding (to the greatest extent possible) of what went wrong, what failure mechanism(s) contributed to the mishap, and what design, manufacturing, or operational changes have been implemented to mitigate the likelihood of reoccurrence. In addition to ERB evaluations and recommendations, the KSC Center Director may empanel outside experts to independently review and evaluate recommendations developed by the

KSC/ELV/ERB, the ELV launch service provider, and other consultants (e.g., Aerospace Corporation) before approving a return-to-flight status.

Engineering Decisions – As shown in figure A-3, once the ERB has addressed a technical issue, it submits recommendations to the appropriate MIT/MIM. In the event of a technical disagreement between the ERB and a MIT or MIM the Project Decision Meeting (PDM) forum can review the issue, although this would be a rare occurrence. The PDM also serves as a forum to discuss technical issues with fleet-wide implications and serves as a necessary step in the process of acquiring funding to address issues which are out of scope for the MIT funding in excess of $200K. Actions requiring funding levels in excess of the $200,000 threshold require submission to the Program Requirements Change Board (PRCB) chaired by the Chief, Program Integration Office.

Engineering Review Board Interactions

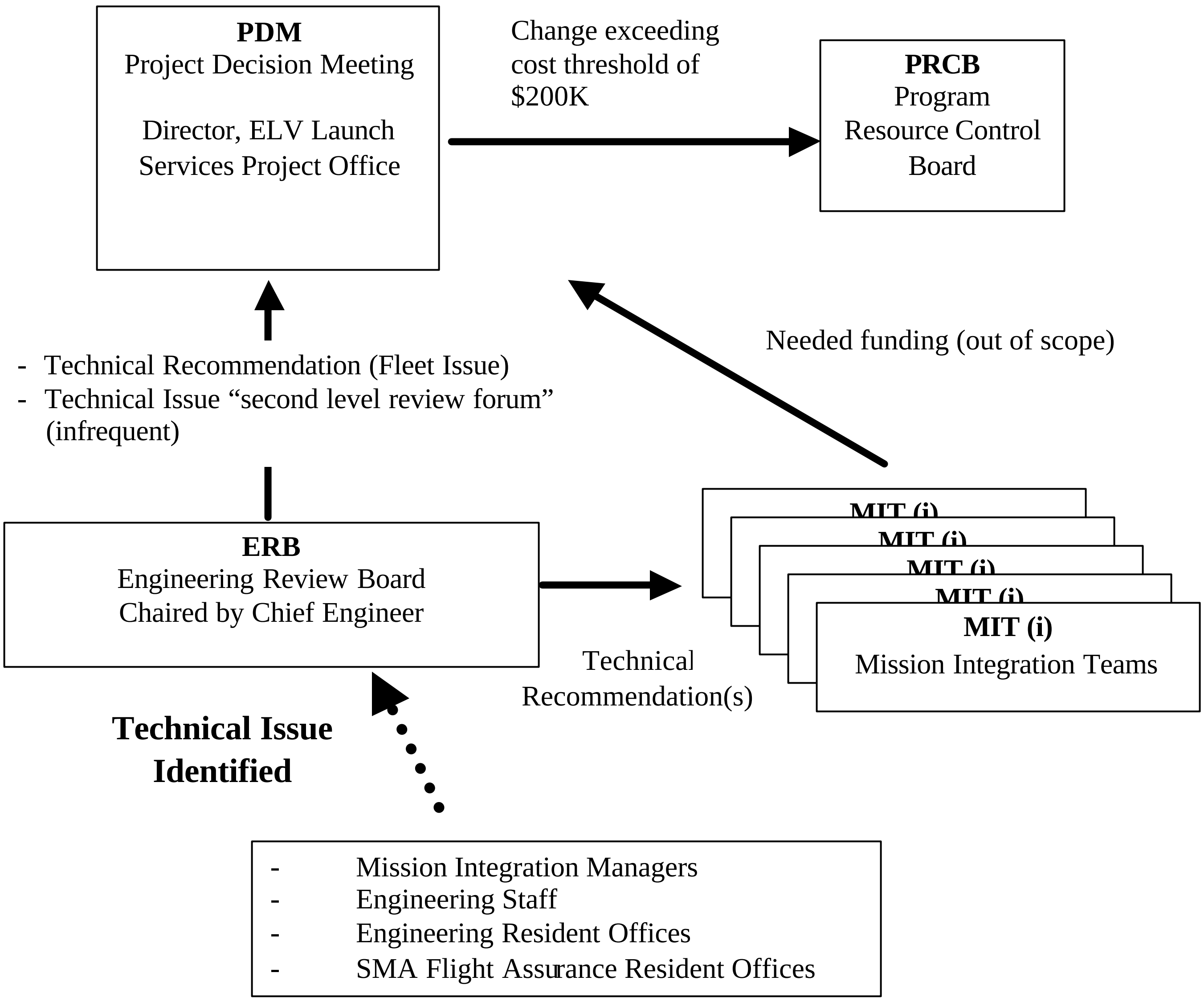


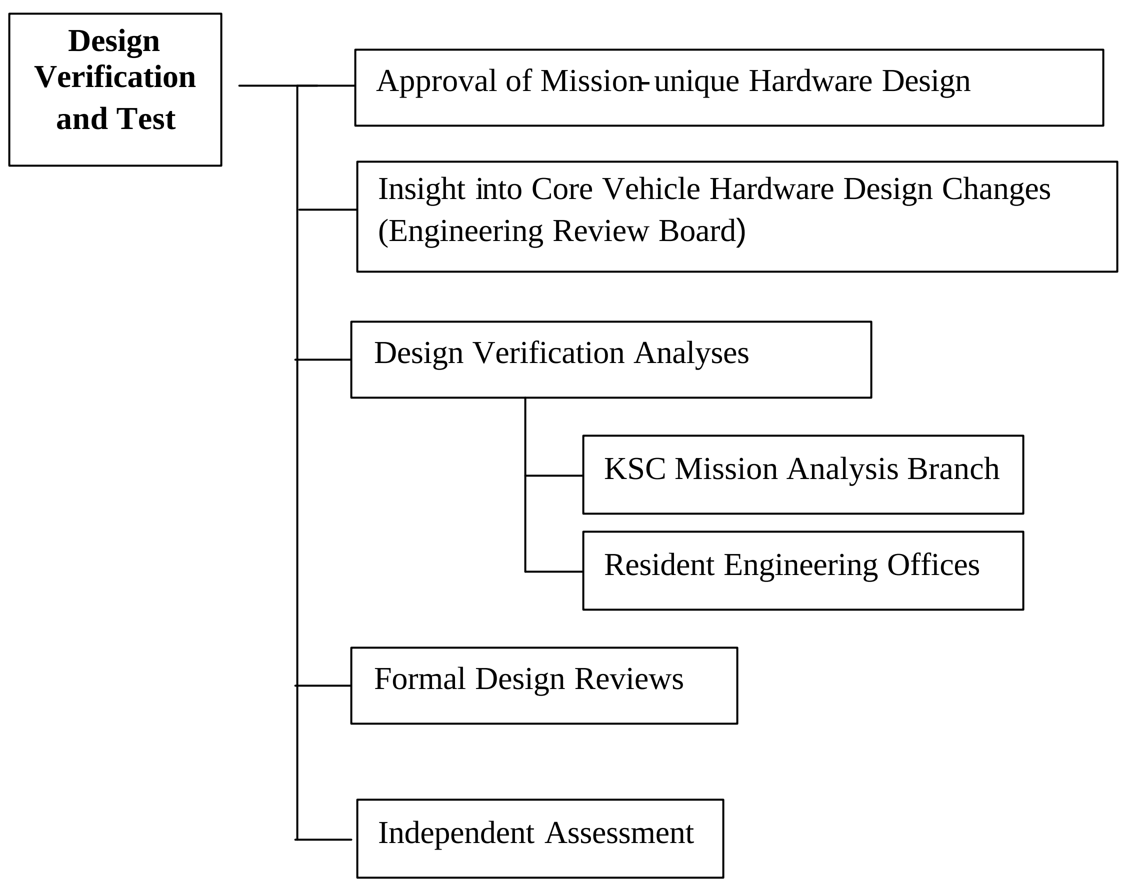
Figure A-3

A.4 Design Verification and Test Assurance Processes

Introduction

NASA ELV design verification processes represent a key strength in the NASA ELV management approach. Design verification processes include:

- approval of mission-unique hardware and software design
- insight into core vehicle hardware design changes
- verification of design through analysis
- use of design reviews (formal boards)
- use of independent design verification consultants and teams



Approval of Mission-unique Hardware Design

NASA KSC-based and in-plant engineering and flight assurance personnel directly participate in engineering decisions related to NASA mission-peculiar hardware and software. The resident offices serve as the first line of contact and interaction for production and design engineering insight. Residents participate in vehicle integrated product team activities, telecons, and meetings. KSC-based subject matter experts, essentially matrixed into individual programs in-work, participate on an as-needed basis. These KSC-based engineers also participate with engineering residents in telecons and video-conferences to work specific issues. KSC/engineering residents also participate in Mission Integration Working Group (MIWG) activities.

LMA/Cassini (Titan IV) Example - Engineering and flight assurance participation begins at the earliest possible moment in the design phase of the (mission-unique) spacecraft/launch vehicle Interface Control Document (ICD). The following activities involved both lead-center engineering (GRC at the time), in-plant engineering, and flight assurance.

- Participation in the original integration contract requirements definition and the Memorandums of Agreement between the Air Force and NASA

- Participation in the draft, approval, and revision process for the Cassini Interface Control Document (ICD) and the Program Requirements Document (PRD). The ICD (an LMA Document) is used to identify all the interfaces between the launch vehicle, spacecraft, and the launch pad. The PRD (an LMA document) defines the requirements at the launch site for Cape Canaveral Air Force Station (CCAFS) facilities, including the launch pad itself.

- Participation in the development and design reviews related to incorporation of the ICD requirements, for both integration hardware and requirements, both stated and derived.

- Tracking and coordinate the initiation of Interface Verification Completion Reports (IVCRs) for the ICD.

Insight into Core Vehicle Hardware Design Changes

Baseline vehicle design and engineering is the primary function and responsibility of the vehicle manufacturer/launch service provider. It should be noted that, in practice, the level of NASA insight varies as a function of the particular ELV launch service provider. The NASA ELV Program Office and SMA organizations at KSC have minimal direct input to, or influence on, the basic design and engineering of the core vehicle. However, they do have “insight” responsibilities, as defined in the current NMI 8610.23, which include participation in meetings, tests, data reviews, reports, inspection records, analyses, and simulations. Ideally the “insight process” enables an understanding of the hardware, software, and management processes used by the launch service provider in the design, analysis, test, launch, and operation of the vehicle.

NASA core vehicle insight is accomplished through the activities of field resident office engineers, KSC cognizant discipline engineers and flight assurance managers. Insight is achieved through access to manufacturers meetings, records, and production facilities. Insight includes witnessing tests, attending reviews and meetings, reviewing documents, and conducting limited analysis. Insight does not involve an approval role. Most importantly, insight is limited by the resources available, primarily staffing. Insight activities identified in NMI 8610.23 include:

- baseline vehicle design, analysis, and configuration management
- design and qualification reviews
- production program reviews, plans, and schedules
- production and system test material review boards
- SMA compliance evaluations
- system tests, post-test data, anomaly resolutions, and failure analyses
- walkdowns, launch site schedules, and plans
- ground support equipment procedures
- work practices and documentation
- post-flight vehicle, tracking, and range data
- post-flight anomaly investigations and closeouts

Design Verification Analyses

Design verification represents an area in which policies and procedures to identify "how deep" and "how wide" are still in development. This is a natural occurrence, representing the merging of two somewhat different design verification philosophies. The GRC-heritage approach, where they typically managed one-of-a-kind, highly complex payloads (Titan and Atlas launch vehicle), was to conduct comprehensive design reviews. The GSFC heritage (Delta and Pegasus) approach was to conduct comprehensive design reviews for first flight configurations, then reduce the number of reviews on reflights of proven designs. The KSC/ELV Program is developing a selective analysis approach based on consideration of payload complexity, cost, uniqueness, and prior NASA analysis verification history for the launch system.

NASA KSC-based engineering and flight assurance personnel directly participate in test planning and review test data developed to verify the design of NASA mission-peculiar hardware. Contractor analyses are routinely reviewed by the NASA engineering team (residents and KSC-based). The NASA assurance approach, or philosophy, is to develop confidence in the contractor's design tools, techniques, and practices.

Depending on the specific contract clauses, independent analysis may form the basis of NASA approval of the contractor design. In selected cases, NASA engineering will conduct independent analysis to validate contractor design activity. ELV engineering and flight assurance personnel, as a matter of practice, conduct no independent analysis of core vehicle engineering. They do, indeed, conduct independent analysis in the case of unique or technically challenging modifications to the vehicle necessary to support NASA requirements. Independent analysis may also be conducted for selected first flight items or subsystems that may have been involved in an in-flight anomaly.

The launch service provider has primary responsible for conducting typical design verification (system/component testing, flight environmental testing, integrated tests, analyses, similarity testing, simulations, etc.) and reviews.

KSC Mission Analysis Branch - The KSC-based Mission Analysis Branch provides ELV analytical support in the following areas:

- Trajectory and Performance
- Guidance Accuracy, and Flight Software
- Guidance, Navigation, and Control Dynamics
- Coupled Loads
- Structural/Stress Analysis
- Environments: Acoustics, Thermal, Shock, and Vibration

Independent analysis is conducted for selected mission-unique items. The decision is typically based on the complexity of the mission.

Currently, an attempt is made to address each of the above areas for every mission, however, due to staffing limitations the question becomes one of depth and level of detail. The expressed concern involves the expectation of providing, with a minimal staff, the same level of insight and independent analyses for every mission including repeat missions and missions which are similar in nature. As noted before, this issue is related to both increasing staff and providing appropriate skill mix.

The Mission Analysis Branch has been able to staff with experienced analysts in critical areas including trajectory/flight design, coupled loads, guidance and controls, stress analysis, and flight software. The available expertise in these areas is primarily a result of consolidation within NASA with several analysts having transferred to KSC from GRC and GSFC. ELV heritage experience includes performing IV&V activities for GOES, SOHO, EOS, Cassini. The analysis branch workforce presently includes:

- Trajectory and Performance: four experienced analysts plus two in training
- Guidance Accuracy and Flight Software: two experienced analysts plus one in training
- Guidance, Navigation, and Control Dynamics: two experienced analysts plus one in training
- Coupled Loads and Vibration Environments: four experienced analysts
- Structural/Stress Analysis: one experienced analyst
- Acoustic Environments: one experienced analyst
- Thermal Environments: one analyst in training

The branch is working to get all relevant codes and models in place at KSC so that they may be used when needed. Guidelines for when IV&V is performed are still being developed. It is anticipated that the criteria will reflect mission complexity, cost, and maturity of launch vehicle.

Resident Engineering Office (Boeing/Delta Example) - NASA contractor engineering support staff covering Boeing/Delta assembly activities at the Pueblo facility routinely perform in-depth mechanical and electrical analysis on selected flight critical hardware to determine parametric sensitivities, margins, and stability. Hardware selected for analysis is typically based on out-of-family deviations, in flight critical component acceptance test data or system data, or manufacturer's uncertainty in environmental or control margins. Activities include structural and electrical analysis.

<u>Formal Design Reviews</u>

LMA/Atlas and Titan Example: NASA Engineering In-Plant Participation in Design Reviews Panels and Boards - The LMA design process used on Atlas and Titan launch vehicles typically employs the following design review forums.

- Systems Requirements Reviews
- Preliminary Design Reviews
- Critical Design Reviews
- Vehicle Engineering Review Boards
- Vehicle Software Reviews
- Vehicle Test Readiness Reviews
- Vehicle Build Reviews
- Vehicle Space Program Reliability Boards
- Vehicle Senior Engineering Review Panels

The NASA engineering resident office employs a matrix marker board approach to assure that each critical review is covered by one of eight engineering staff members. It is noted that KSC-based engineers also participate (remotely) in many of these Denver-based meetings as well.

<u>Independent Assessment</u>

Independent assessments are part of NASA's willingness to ensure all management, technical, administrative, manufacturing, operational, and failure investigations issues have been resolved and independently reviewed. For example, independent teams were chartered for the upcoming Terra launch, NASA's flagship earth observation system mission and the Cassini launch, NASA's space science mission to Saturn.

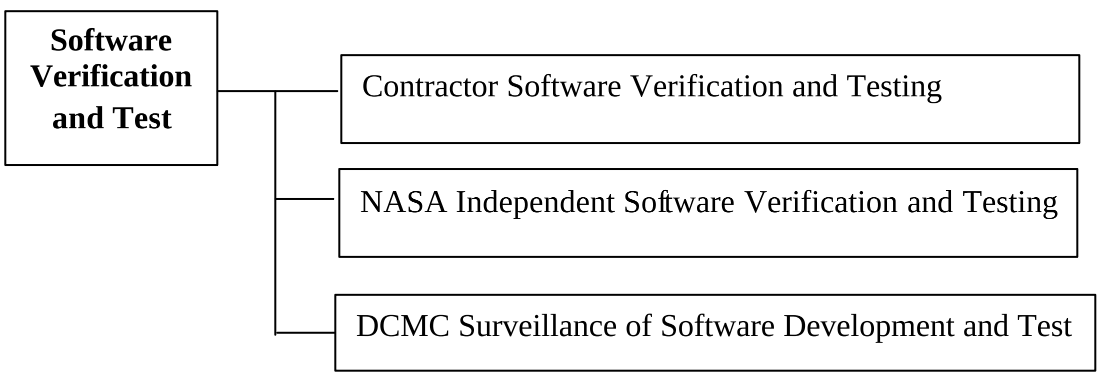
LMA/Atlas Terra - A 12-person team, representing 400 years of experience, examined the KSC and GRC launch service management process during KSC's transition as NASA's lead center for ELV launch services. This team examined current ELV insight approval processes, launch site operations, first flight items, unique Terra interfaces, and ELV program transition shortcomings. The team found that the Terra insight/approval process supported the flight worthiness of the Terra AC-141 launch and the KSC/GRC process was consistent with expectations for flight worthiness.

LMA/Titan IV: Cassini Mission - The Cassini space science mission was another NASA program which receive special review atypical of most commercial or government launches. Powering the Cassini spacecraft to Saturn, the spacecraft has three radioisotope thermoelectric generators or RTGs, which contain plutonium-238 to generate direct current electricity. The Cassini launch must passed interagency nuclear safety review requirements. Teams from both Jet Propulsion Laboratory and KSC scrutinized the launch vehicle. In addition, an External Independent Readiness Review (EIRR) team was established for Cassini. Under NASA EIRR contract, Aerospace Corporation of El Segundo, CA, reviewed the design and build of the major Titan IV vehicle components flown for the Cassini mission. Special attention was given to the solid rocket motors. This included oversight of all activities at the solid rocket motors contractor facility including build and propellant casting of segments.

A.5 Software Verification and Test Assurance Processes

NASA has approval authority over contractor test methods and data used to verify mission-unique software and some modifications to core vehicle software. NASA exercises insight for routine software verification activities. Software verification testing may be conducted by NASA in cases where complex high-value spacecraft are involved. Formal software design reviews are routinely employed and independent assessment is conducted on a case by case basis.

Historically, the verification of guidance and flight software for NASA ELV missions has been implemented somewhat differently by the responsible design centers (GRC or GSFC), reflecting differences in launch vehicle design and mission needs. For the Atlas/Centaur vehicle, emphasis has been placed on guidance and sequencing through review of software test results. Various guidance accuracy analysis tasks have also been performed. For the Delta II and Pegasus vehicles, the emphasis has been placed on software design reviews and review of relevant mission and core vehicle documents. Specific analysis tasks have also been performed when warranted.



KSC is currently developing an integrated software IV&V approach which will combine aspects of the historical Delta and Atlas approaches. This should allow KSC to understand and review the launch service provider process that they use for software verification and assure that all necessary items have been checked. The capability to perform this insight will be applied, as necessary, for all ELV's under KSC responsibility. Mission-unique changes to core vehicle flight software will be reviewed. It is expected that the basic core vehicle flight software will be well understood and checked out for each NASA mission. This checkout will begin with the start of the mission integration process and continue through final documentation of the flight software. Core software is seldom changed for the more mature vehicles. When changes do occur there will be very intensive KSC/engineering involvement. Examples are provided below describing the traditional Delta and Atlas software verification approaches.

Contractor Software Verification and Test

Boeing Delta/FUSE Mission Example - Mission-peculiar software is routinely subject to intense scrutiny by both Boeing and NASA ELV engineering. Boeing validates flight software in the Systems Integration Laboratory at Huntington Beach which allows full flight simulation capability. NASA is heavily involved in mission design activity and occasionally in the development of flight constants necessary to implement the design. NASA conducts an independent review of the Boeing guidance navigation and control (GNC)/auto-pilot design.

LMA/Atlas Flight Analogous Simulation Test Review (FAST) - This review involves a complete simulation of flight software followed by a two week, in-depth review of all data.

NASA Independent Software Verification and Testing

Boeing/Delta NASA use of software IV&V - In the case of Delta launches NASA typically employs the Aerospace Corporation to conduct independent verification of flight software and mission constants. An excerpt from their Delta/Fuse mission report observed: " No deficiencies were noted in the Boeing verification process. The software code is the same as has been flying on Delta II for some time and no patches or retests have been made for FUSE. It is pointed out that FUSE will be the second flight for a 3-GEM configuration vehicle and Aerospace has not performed an independent evaluation of the control system requirements and have only reviewed the mission constants (sic) set necessary for implementation of given control requirements."

LMA Atlas/GOES Mission Example - KSC/ELV Engineering is responsible for software verification. GRC software verification support is currently in place for the next three Atlas missions, GOES-L, EOS/TERRA, and TDRS-H. For subsequent Atlas launches, software IV&V will be conducted entirely by the KSC-based mission analysis team at KSC. Software IV&V includes the following areas:

Guidance Validation: This review provides a final validation of flight constants. GRC uses a Fortran three degree-of- freedom simulation of Atlas vehicle and a replica of the guidance flight software modules. This activity is considered of extreme importance for planetary missions.

Accuracy Analysis: Monte Carlo-like simulations are conducted for three-sigma variation (root sum of squares combination) in inertial measurement system accuracy. These variations are used to bound potential errors in injection accuracy.

Stability Analysis Validation: Major staging events are simulated as well as passage through maximum dynamic pressure (max-Q).

As noted above, the LMA Flight Analogous Simulation Test Review (FAST) involves a complete simulation of flight software followed by a two week, in-depth review of all data. Typically this review is also supported by five or six GRC-based software experts as well as KSC mission analysis staff. Typical software experts from the controls, guidance, fluids, flight sequencing, and solid motor sequencing areas will participate in the review The FAST review validates all flight software with the exception of the inertial measurement system.

DCMC Surveillance of Software Development and Test

Boeing/Delta - KSC/SMA/FA delegates software quality assurance functions to DCMC. These functions include, but are not limited to, verifying that all Boeing/NASA quality, configuration management, and test provisions have been followed. Abbreviated excerpts from the proposed Letter of Delegation convey a sense of what surveillance activities DCMC will perform:

"The Agency (DCMC) shall perform Software Quality Assurance per instructions and requirements outlined in the Agency Product and Manufacturing Assurance (P&MA) Plan on a non-interference basis.

The Agency shall perform process control audits on the contractor's design, development, and implementation/release of (CAT A) software, to include new developments of flight software (when required) and unique mission constants. Software reviews may consist of attending critical design reviews (CDR's), configuration reviews, and the like for software items. The Agency shall periodically review contract deliverable (Category A) software documentation, (on a sample basis), for correctness, consistency, and compliance with contract format and content requirements.

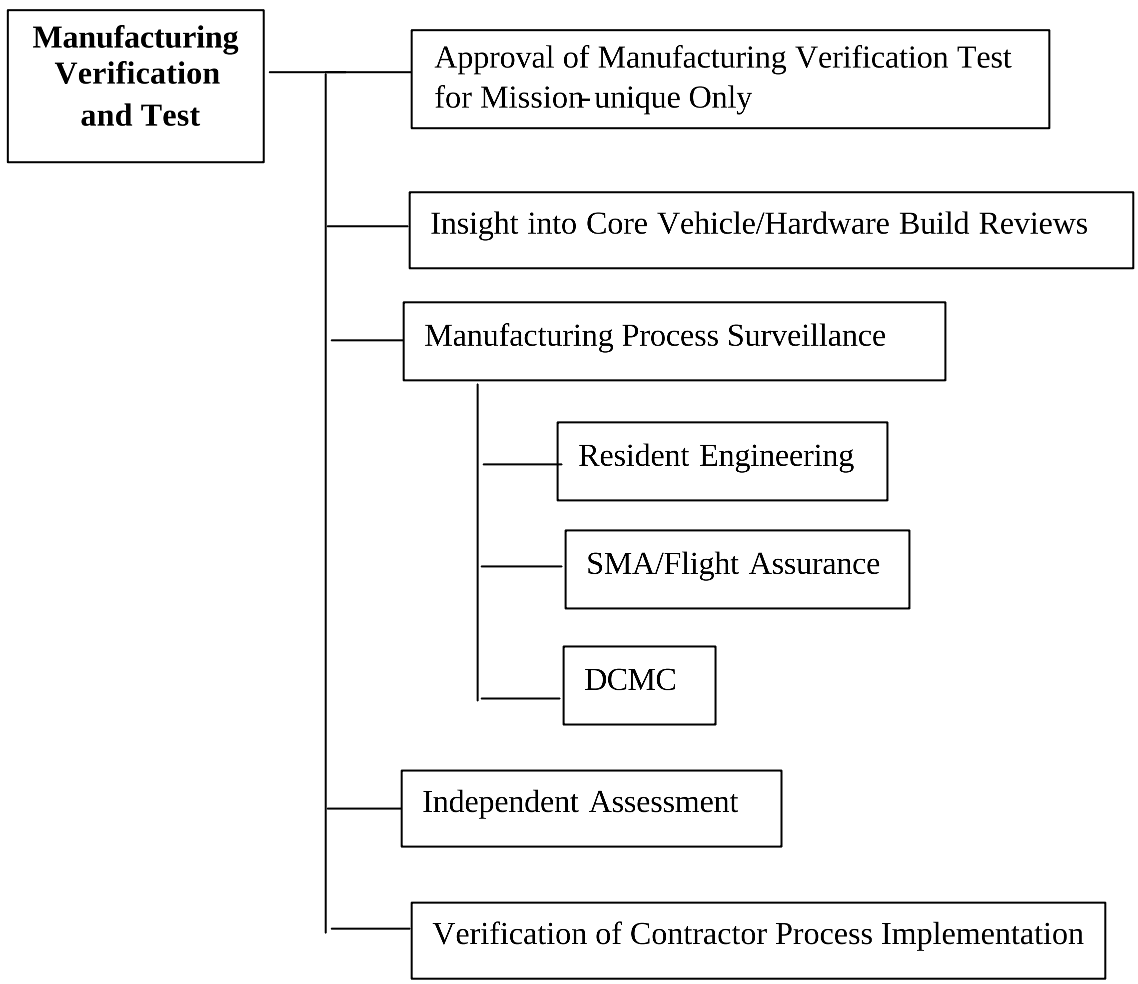
LMA/Atlas – The current DCMC surveillance plan (subordinate to the LOD) describes software surveillance activity as follows:

"Software surveillance involves the review and assessment of software development and management on the Atlas program. Included in Atlas software activities are flight software maintenance/updates to support mission requirements. DCMC LMA software quality assurance specialists with support from DCMC engineering personnel, perform the following tasks:

- review software contract deliverables and applicable command media
- attend software build reviews
- review and trend Atlas software trouble reports and software change requests
- monitor FAST and other systems integration laboratory activities
- participate in software audits."

A.6 Manufacturing Verification and Test Assurance Processes

Manufacturing assurance processes begin with NASA approval authority for NASA mission-unique hardware test and qualification activities. It is worth noting that this represents only a very small percentage of the integrated launch system. Core vehicle assurance comes through the insight process centered on participation in tests, hardware build reviews, and pedigree reviews. In some cases independent assessment performed by the Aerospace Corporation is conducted to certify proper disposition of problems encountered in production (build paper). Another element of insight is manufacturing surveillance carried out by DCMC in support of NASA and other customers. Limited formal verification of contractor assurance process implementation is conducted at the present time. Discussions are underway to find resources necessary to routinely verify implementation of the many assurance processes certified under ISO 9001, and/or listed in contract quality plans, systems effectiveness plans, or equivalent contract assurance requirements.



Approval of Manufacturing Verification Test for Mission-Unique Only

Current NASA ELV Program engineering field offices are located at the following facilities:

- Lockheed-Martin, Denver, Colorado
- Boeing Corporation, Huntington Beach, California
- Boeing Corporation, Pueblo, Colorado
- Boeing Corporation, El Paso, Texas
- Orbital Corporation, Chandler, Arizona
- Vandenberg Air Force Base, Resident Office

The teams have cognizance of all prime flight critical mechanical and electrical hardware assemblies. Responsibilities include monitoring the current configuration of all prime flight critical mechanical and electrical hardware assemblies, tracking all future Class I modifications and the effects of those modifications on vehicle integration, and the qualification baseline and system reliability. Resident offices are also responsible for evaluating the qualification baseline and acceptance test program for mission-peculiar hardware and first flight items. Resident offices perform hardware pedigree reviews and provide recommendations to NASA concerning all discrepancies involving flight critical assemblies, including any in depth mechanical and electrical analyses necessary to characterize the impact of the discrepancy on mission reliability.

As required, resident engineers perform technical evaluations of the launch vehicle manufacturer's technical reports, quality reports, procedures, and drawings. They also participate in management, engineering, quality, and product reviews in addition to attending meetings on hardware design, manufacturing, testing, inspection, anomaly resolution, and major component pre-ship reviews. Engineering offices place special emphasis on mission-peculiar hardware and flight critical first flight items.

Insight into Core Vehicle/Hardware Build Reviews

LMA/Atlas Example of Supplier Management - The Atlas build reviews are referred to as "Mission Success Reviews." The Denver engineering resident office routinely participates in MSR's at key Atlas/Centaur suppliers. Suppliers that are routinely audited using the MSR process are:

- Honeywell
- Harlingen
- Pratt & Whitney
- Rocketdyne
- Lockheed (Binghamton, New York)
- Marconi
- Thiokol
- Plant 19 (former General Dynamics Tank facility in San Diego

Denver resident office personnel routinely participate in production/manufacturing integrated product teams (e.g., Centaur tank, Atlas tank, and fairing), including LMA and component suppliers.

Boeing/Delta Example of Manufacturing Production Review - Boeing also conducts a series of build reviews which provide an opportunity for NASA engineering and flight assurance personnel to gain valuable insight into core vehicle production issues. Major hardware component build reviews are conducted for the launch vehicle elements/activities listed below. NASA engineering (KSC and residents) as well as flight assurance participate in all Hardware Acceptance Reviews (HAR's) at the Delta prime contractor and major subcontractors.

Typical Delta HAR's are:

- Second Stage Engine
- Main Engine
- Fit-check
- Graphite-Epoxy Motors (GEM's)
- Booster Vehicle Subsystem
- Turnover Review
- Interstage
- Second Stage & Fairing
- Critical Design Review
- Mission Modification Review
- Design Certification Review

LMA/Titan Hardware Production Oversight - While not a requirement under existing MOA's between NASA and the Air Force, the Denver resident engineer office participates in Titan II build reviews. The HAR's give NASA and the Aerospace Corporation the opportunity to review all the build documentation, and nonconformance data on the respective hardware. The HAR's provide valuable insight to the different processes and function of the vehicle and its major components. These reviews are coordinated by the Aerospace Corporation with full participation from NASA. All hardware produced for Titan is reviewed prior to shipment either from the MEC or from LMA in Denver to CCAFS. Flight assurance personnel participated in all the HAR's for the core vehicle and its major element contractors (MEC's).

Manufacturing Process Surveillance

Denver Resident Office Quality Assurance Functions and Tasks - The Denver engineering resident office monitors traditional quality assurance activities including:

- quality assurance issues
- systems engineering issues
- avionics issues

The resident office engineers also participate in Parts Control Board (PCB) and Material Review Board (MRB) meetings as well as in the LMA ISO 9001 Working Group.

SMA/Flight Assurance (LMA Example) - The KSC/FA organization, through its resident assurance engineer (SAIC contractor) in Denver, routinely participates in the production process at Denver. Some of the items covered by the resident assurance representative are engineering review board meetings on Class I design changes, problem report reviews and closure, major nonconformances documented during production, and other miscellaneous activities. The resident assurance engineer also participates via telecon with some of the flight assurance and engineering meetings at KSC. The FAM also monitors the manufacture of the Titan core vehicle, the Centaur upper stage, and the SRMU's. Activities include Class I design changes, nonconformances during manufacture that required an MRB disposition, and general processing concerns at each facility. The FAM also participates in the System Effectiveness Reviews required of LMA by the Air Force. These reviews are held to understand processing problems and initiatives both at LMA and its four MEC's. Further, the FAM conducts monthly reviews of Corrective Action Problem Summaries (CAPS) initiated by LMA and/or its MEC's. These reviews are held to determine the adequacy of CAPS closures by the contractor. The FAM also attends all of the HAR's conducted on the Titan core, Centaur, and the MEC's. These reviews are held to review the build documentation, nonconformance data, and test results for the major components of the Titan IV vehicle. These are held in parallel with like reviews conducted by Aerospace Corporation.

LMA System Effectiveness Reviews (SER's) - In the past, under GRC management, engineering and flight assurance personnel participated in LMA System Effectiveness Reviews (a review of the product assurance system) conducted in accordance with the in-place Air Force contracts for both Titan and Atlas launch vehicles. These reviews are held on a semi-annual basis and are used to address issues and concerns on the Titan program that affect mission assurance, and to review programs and initiatives being implemented by LMA and/or its MEC's. These reviews provided NASA with valuable insight to the LMA mission assurance activities as well as the opportunity to meet their counterparts at LMA. It is noted that these reviews are evolving toward an ISO-style internal-audit format. It remains to be seen whether or not KSC/ELV/SMA will provide the resources necessary to routinely support these reviews.

Defense Contract Management Command (DCMC) Surveillance - There is not yet, in-place, a coordinated KSC/SMA approach defining DCMC's role within an overall assurance management strategy. Current DCMC letters of delegation (LOD) represent agreements which were in place under GSFC and GRC management of ELV's. KSC/SMA is currently developing a new LOD for the Boeing/Delta program.

DCMC Support for Atlas and Titan - Titan and Atlas production and daily events are monitored by the DCMC. The DCMC has offices at LMA in Denver as well as all the major suppliers. The DCMC role at LMA facilities reflects strong USAF influence in developing requirements and is oriented toward surveillance of a single quality process across multiple government customers. They act only in an oversight role for Atlas vehicles and they do not have hardware approval authority (with the exception of Titan vehicles) at Denver or with the suppliers. In the case of LMA, DCMC is currently working under a GRC LOD. The thrust of the LOD is direction to conduct surveillance. The surveillance plan is the key document delineating specific surveillance activities.

The current implementation plan includes audit, manufacturing process surveillance, reliability and maintainability process review, software surveillance, engineering design and development evaluation, observation of the Material Review Board Process (MRB), configuration management surveillance, transportation and shipping process reviews and other administrative support assignments.

DCMC Support for Boeing - The first line of manufacturing assurance is afforded by the ISO 9001 certified processes described in the Boeing PAIP. The contractor has primary responsibility for implementing those processes and assuring that they remain stable, capable, and in control. NASA SMA/FA has insight, albeit limited by available surveillance resources, into prime contractors and major subcontractors through the DCMC personnel resident at manufacturing facilities. The quality assurance functions to be performed on the Boeing/Delta program are set forth in an LOD between NASA and DCMC. The current LOD provides DCMC support of approximately 7000 hours per year at Huntington Beach and 680 hours per year at the Pueblo manufacturing facility. All DCMC personnel report to the UNISYS Flight Assurance Manager at Huntington Beach, California.

DCMC support typically includes such activities as tracking nonconformances and corrective actions, auditing compliance to the contractor's quality and product assurance plans and processes, conducting parts reviews and inspections, witnessing assembly and test operations, attending contractor-established reviews and monitoring the MRB.

Independent Assessment

Manufacturing activities are subject to periodic independent assessment of hardware fabrication and test. Two examples are provided below:

Boeing/Delta - Aerospace Independent Assessment Example - Each NASA Delta vehicle is subject to an independent contractor (Aerospace Corporation) review of all build paper and test paper deviations, problem reports, non-conformances, or other discrepancies encountered during either fabrication or testing. This review examines disposition of these discrepancies. The Aerospace Corporation refers to this assurance activity as a pedigree review. The pedigree review activity encompasses both hardware and software manufacture/development, and test. The Aerospace Corporation/FUSE review specifically highlighted issues or concerns (all resolved) related to Stage II propulsion, Stage II pneumatics, Stage II regulators, Stage I vernier engines, Stage I solenoid valves, Stage I engine structures, Stage I and II power and control systems, Stage I and II batteries, and vehicle software.

LMA/Titan II Example – Aerospace Independent Assessment Example - The Aerospace Corporation provides independent assessment to the USAF in connection with the manufacturing and test of Titan II and Titan IV hardware and software. The following paragraphs, abstracted from the NASA-managed Titan IIG-7 mission report, characterize the scope and depth of an Aerospace Corporation build review:

"Aerospace personnel have been involved in the refurbishment and processing of Titan IIG-7, from initiation of core modifications, to processing and acceptance testing of the liquid rocket engines, and acceptance testing of guidance, control and electrical components. Factory testing, as well as launch site acceptance and major system testing, have been reviewed and evaluated for anomalous out-of-family performance. Pedigree packages and qualification testing data on critical components have been reviewed and those components have been found acceptable for flight. Ground systems, facilities, and equipment have been reviewed and their capability to support launch processing have been verified. Aerospace participated with the contractor, LMA, in the Vehicle Readiness Review Team effort to review all processing activity at the launch site, including anomalies and their resolution. All payload integration activities and analyses have been reviewed and the booster to satellite vehicle interface requirements have been identified and verified."

"All systems analyses have been verified, including loads and dynamics, separation, trajectories, and thermal and dynamic environments. Post-flight analysis of previous Titan vehicles and an assessment of the lessons learned were conducted for potential impacts to Titan IIG-7. All Corrective Action Problem Summary (CAPS) impacts were technically evaluated, and have been lifted for this vehicle. The Titan IIG-7 TAG reference trajectory has been validated, and the booster stage II aimpoint and steering data, trajectory performance database, FMH K-factors, propellant margin requirements, ground station telemetry coverage, radio frequency environment, and range safety data have been independently validated, and are acceptable for flight."

"Aerospace is the sole provider of outside verification and validation of Software, Guidance Navigation & Controls (GN&C) and loads for Titan II. The Titan II Flight Program, version XX-U001-7.1-08, was verified by the Aerospace Corporation for the Titan IIG-12 / NOAA-K mission. The binary diskette for the flight code was verified by Aerospace and delivered to the launch site for independent verification of the flight software load on Titan IIG-7. The flight parameters diskettes and the primary and back-up IMU calibration diskettes that are used for independent software load verification for the Titan IIG-7 mission have been verified and validated. All flight parameters are verified to be consistent with the contractor-provided scientific-formatted listing of the flight and IMU parameters. The Titan IIG-7/QuikSCAT booster GN&C/Software mission assurance activities have been completed, certifying that the booster flight software meets mission requirements and supports the mission in the areas investigated."

Verification of Contractor Process Implementation

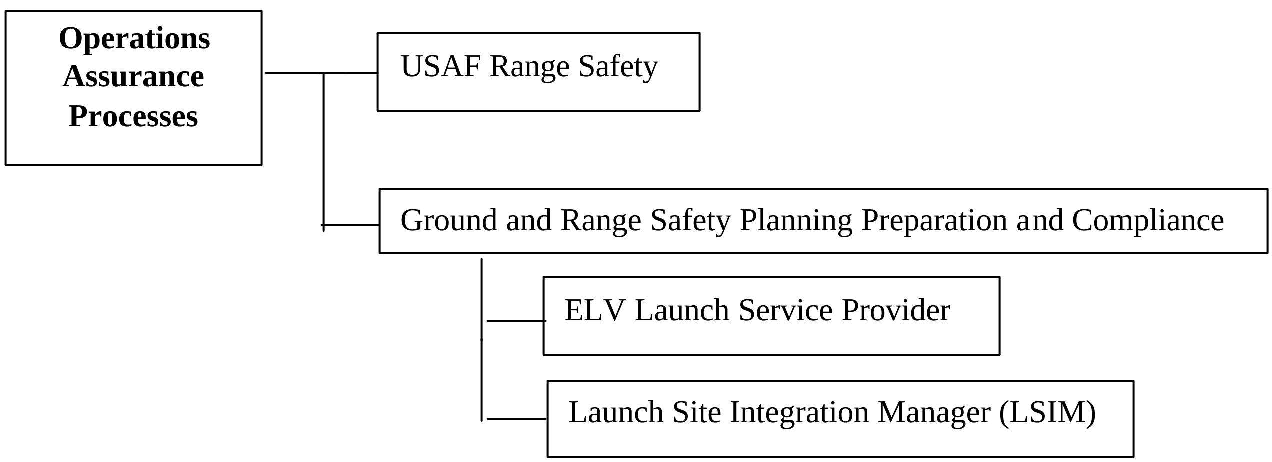
LMA - NASA "Over the Shoulder Audit" - A past practice of the GRC flight assurance organization, NASA FA managers would participate in LMA internal audits (including major subcontractors) scheduled for the year to verify contractor process implementation and to validate the fidelity of the LMA audit process. Again, it remains to be seen whether or not the SMA/ELV/FA organization will provide resources necessary to resume this surveillance activity.

Boeing - Internal Audit - NASA previously did not participate in Boeing internal audits conducted in preparation for the formal recurrent ISO certification audits. SMA FA now requires DCMC representatives to participate in Boeing internal audits as a means to verify process implementation.

A.7 Operations Assurance Processes

Operations assurance processes include all of those activities centered around public safety, worker safety, and payload mission assurance.

In the case of commercially obtained launch services the primary responsibility for safety planning and compliance lies with the launch service provider. The ELV Program Launch Site Integration Manager is responsible for assisting the service provider and the spacecraft customer in fulfilling all safety (and other) launch site requirements. The NASA SMA organization is responsible for assuring the safety of activiities that take place in NASA payload processing facilities. Ultimate range safety responsibilities reside with the Base Commander and are codified in the EWR 127-1 requirements document.



<u>USAF Range Safety</u>

The launch service provider has primary responsibility for interfacing with the USAF 45th Space Wing at KSC and the 30th Space Wing at VAFB to assure compliance with EWR-127-1 requirements for range safety and flight termination system design, manufacturing, and test. NASA/SMA has an insight role in maintaining knowledge and understanding of range safety policy.

<u>Ground and Range Safety Planning Preparation and Compliance</u>

Launch Service Provider Responsibilities for Safety & Assurance - The launch vehicle provider and the USAF have primary responsibility for ground safety activities related to commercial launches from the Cape Canaveral Air Force Station. NASA owns and operates Space Launch Complex (SLC) 2 at VAFB and is responsible for ground safety process implementation at that site.

Generic (All Launch Services) Range And Ground Safety Responsibilities of the Launch Service Provider - Launch service providers are responsible for range support and making provisions for the necessary range approval and scheduling of supporting services for each launch which typically include the following:

- RF radiation clearance
- Fire protection
- Base security, including security police and badge control
- Equipment support
- Shop and laboratory services
- Fluids, gases, and propellants
- Range scheduling
- Range safety functions
- Meteorology
- Communications (local and downrange) data circuits
- Environmental health services
- Metric C-band beacon (radar)
- Telemetry
- Video and still camera coverage of launch
- Station acquisition predictions
- Non-standard servicetracking services (as needed)

Roles And Responsibilities Of Launch Site Integration Manager (LSIM) - The LSIM is the point of contact for customers with payloads to be launched on an expendable launch vehicle and serves as liaison between the customer and KSC management. The LSIM functions in two major arenas: project planning and the ground operation phase at KSC. The LSIM is considered the customer's principal launch site integration interface and as such becomes a source of authority to the payload customer regarding KSC policies, roles and responsibilities, capabilities, and requirements. For major or unique payloads, such as HST, EOS, Cassini, the LSIM may be assigned six to eight years in advance of launch to work long-lead issues.

Other responsibilities include:

- assuring that KSC management and working elements are satisfied with payload plans
- assuring that payload customer is satisfied with KSC planning for their support and operations
- coordinating development of the Launch Site Support Plan

<u>LSIM Safety and Assurance Roles</u>

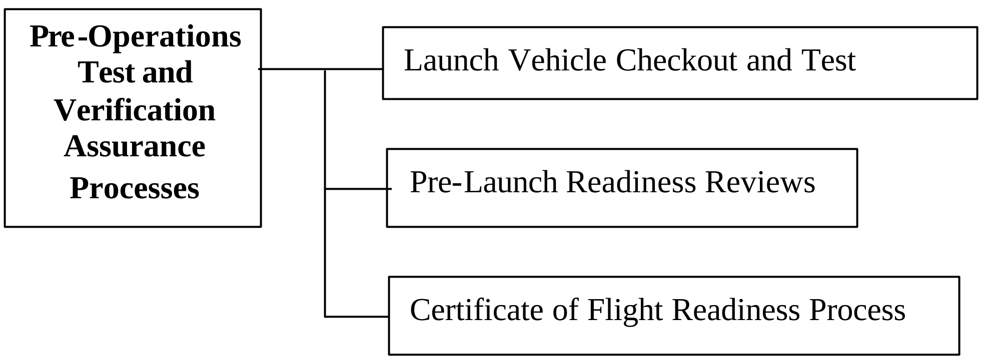
The LSIM plays a key role in coordinating and assuring compliance with the documentation and planning required by the range under the requirements of EWR 127-1. The LSIM is responsible for coordinating and verifying the customer development of the Payload Safety Package and the presentation of the document at the

Ground Safety Review. The LSIM also verifies the need for special safety waivers and coordinates NASA/SMA surveillance of hazardous operations at least 24 hours in advance.

The LSIM is responsible for assuring that Material Safety Data Sheets (MSDS's) are provided for all hazardous (toxic, biological, and/or radiological) materials. The LSIM is also responsible for confirming that customers have training regarding hazardous material storage, handling, and disposal. The LSIM also plays a safety clearance coordination role with regulatory agencies including, the Department of Energy, the EPA, the State of Florida, and Brevard County, as well as KSC Biomedical and KSC Protection Services.

A.8 Pre-Operations Test and Verification Assurance Processes

Critical NASA assurance activities include the witnessing and verification (insight) of tests and procedures involved in launch vehicle assembly at the launch site and final integration and test on the launch pad. Certain key tests are considered NASA approval items in the early stages of integration. During the final six to nine days on the pad NASA involvement is almost entirely on an approval basis. NASA ELV/engineering, SMA/flight assurance, SMA/quality assurance personnel, and SMA/safety personnel are involved in monitoring on-pad integration activities including final test and check-out of the vehicle. In addition to the test and verification activities, NASA employs a well-documented and proven launch readiness review process culminating in the signing of a CoFR.



<u>Launch Vehicle Checkout and Test</u>

LMA/Atlas Example - The key event in the Atlas pre-flight preparation is the Wet Dress Rehearsal (WDR) in which cryogenic propellants are loaded, tanks are pressurized, and the entire countdown sequence is carried out all the way to launch. The WDR is then followed by a "tiger team" activity lasting a week in which all WDR data are reviewed and all non-conformances are evaluated and corrected. NASA engineering and flight assurance personnel also participate by shadowing LMA personnel performing vehicle walkdown/checklist activities.

LMA/Titan IV Cassini Example: NASA Flight Assurance - NASA GRC Flight Assurance Managers (FAM) attended the ground operations, system integration, and management working group meetings and the integration of Cassini to the vehicle and the pad. They reviewed processing problems encountered during vehicle processing at CCAFS for the first Titan IVB (TIVB-24). This data was used to determine possible processing problems on the Cassini vehicle. They compared Vertical Integration Building (VIB) processing and testing changes made between the TIVB-24 and TIVB-33 core vehicles to confirm all necessary processing and testing was planned and documented. FAM's (as well as KSC-based engineers) participated in the final vehicle readiness reviews of procedures and test data, along with out-of-sequence processing documents. In addition, FA and engineering reviewed all nonconformance and work around documents for possible impacts or oversight of prospective problems.

Typical Launch Service Pre-flight Test and Checkout - The scope of NASA insight and approval in a typical pre-launch test and verification flow is captured in the abstracted sections below derived from the KSC/ELV engineering electrical/mechanical pre-launch test verification and walkdown plan. While not formally documented as a KDP, this plan is typical of the operational level documentation applied to ELV Programs at KSC. All of these activities typically involve ELV/Program discipline engineers and SMA flight assurance and/or quality assurance managers.

- monitor key launch vehicle and payload transportation and handling offload and hardware receiving events
- monitor major system level tests (i.e., propulsion, controls, hydraulics, electrical flight simulation, etc.)
- monitor solid motor buildup
- observe payload processing events (i.e., fitting attachment , spin balance, etc.)
- observe upper stage motor processing, build-up, balancing, mating, and ordnance installation
- monitor spacecraft processing, weigh/mate operations, installation of clampband, and erection
- monitor all stage erection and mating activity
- monitor spacecraft erection and mate
- monitor mated major systems tests (power-off stray voltage checks, etc.)
- participate in all vehicle walkdown activities

SMA Verification Activities - As part of the pre-launch readiness verification process SMA/FA will typically:

- verify that all high level test data is “in family” (e.g., engine hotfire test data)
- review all special attention items and verify that all fleet issues are resolved pertinent to the relevant hardware
- verify that any open items or incomplete hardware is properly tracked
- verify that all special inspections to this point have been performed satisfactorily
- verify that all waivers and deviations to this point are closed
- provide surveillance of hazardous/high-risk operations

Pre-Launch Readiness Reviews

NMI 8610.24, "Expendable Launch Vehicle (ELV) Launch Services Prelaunch Reviews" establishes the ELV prelaunch review process necessary to assess and certify the readiness for launch of the launch vehicle including separately provided upper stages and supporting launch services provided by commercial companies or by DoD. In accordance with NASA accountability for program mission success, NASA management assesses and certifies the readiness of the launch vehicle (and payload) preparatory to launch through a structured prelaunch review process. Required reviews include:

Center Director's Launch Readiness Review (CD/LRR) - The CD/LRR is held to assess the readiness of the ELV and/or upper stages to proceed with launch site operations. The CD/LRR is chaired by the NASA Center Director of the field installation responsible for management of the NASA Launch Services Projects, or his/her designee, and is held approximately one to two months before launch.

Associate Administrator's Mission Readiness Review (MRR) - The MRR is held to certify the readiness to proceed toward launch countdown. The MRR is chaired by the Associate Administrator for Space Science (AA/SS) and the Associate Administrator of the spacecraft program office (when other than AA/SS), or their designees. The MRR is held at NASA Headquarters after the CD/LRR and approximately one month before launch.

L-4 Review - KSC conducts a Flight Readiness Review (approximately L-4) which is performed prior to the initiation of the final preparations for launch. These reviews include the description of the launch service, mission-unique and first flight items, and anomaly closures from previous missions. At the conclusion of these meetings a poll is conducted to assure that all parties responsible for mission success agree with proceeding to the next milestone.

Launch Readiness Review (LRR) - The LRR is held to update the mission status and closeout actions from the previously held CD/LRR and MRR, and certify the readiness to proceed with initiation of the launch countdown. The LRR is chaired by the NASA Center Directors of the field installations responsible for management of the NASA Launch Services Projects, or his/her designee, and is held approximately two days before launch at the launch site.

Mission Director's Flight Readiness Review (FRR) - The FRR is held to update the mission status, closeout actions from the LRR, authorize approval to proceed into launch countdown, and sign the CoFR. The FRR is chaired by the Mission Director and is held the day before or day of launch at the launch site. Following the FRR and initiation of launch countdown, the final critical milestone before launch is the commit-to-launch poll. The poll, conducted by the NASA Launch Manager for the Mission Director approximately five minutes before launch, asks representatives from all organizational participants to reconfirm their readiness to launch.

NASA may conduct other reviews as appropriate and necessary in preparation for launch. These may include, but are not limited to, Mission Requirements Reviews, Critical Design Reviews, Design Certification Reviews, Preship Reviews, Ground Operations

Reviews, and Project and Launch Manager's Reviews. Generally, the mission spacecraft undergoes a parallel prelaunch review process with both the spacecraft and ELV jointly reviewed in the MRR, LRR, and FRR.

Certification of Flight Readiness Process

Following the completion of the Flight Readiness Review, a CoFR is signed by the following parties:

- NASA Spacecraft Mission Director
- NASA Launch Manager (NLM)
- USAF Spacelift Commander
- Launch Service Provider

The NASA SMA organization signs the back-up CoFR that supports the signature of the NASA Launch Manager.

During the launch countdown, the NASA Launch Manager polls the following parties:

- Spacecraft Mission Director
- NASA SMA
- NASA Mission Integration Manager
- NASA Chief Engineer
- NASA Advisory Team

SMA Role in the CoFR Process - Past procedure for obtaining SMA signature on the CoFR has represented an informal collation of information. However, it is anticipated that future SMA CoFR processes will be fully documented and formally incorporate criteria describing the basis for the concurrence (i.e., knowledge and understanding of assurance process implementation.)

Appendix B
Compendium of Documents Reviewed

ELV Program Office References

- KSC/ELV Program Organization Chart, FY 1999
- ELV Activities calendar, Current
- NMI 8610.23 Technical Oversight of ELV, August 1992
- NMI 8610.24 ELV Launch Services Pre-Launch Reviews, October 1993
- Contract SMA Provisions (Small ELV)
- Contract SMA Provisions (Medium ELV)
- OSF Enterprise Strategic Plan, FY 1999
- ELV - ISO 9001 Documented Processes, FY 1999
- KSC Strategic Management Plan, FY 1999
- NPG 7120.5A Program and Project Management Processes and Requirement, April 1998
- Transition Plan for the Lead Center for the Acquisition and Management of ELV Launch Services at the John F. Kennedy Space Center, January 14, 1998
- Program Management Plan, Transition Plan for the Lead Center for the Acquisition and Management of ELV Launch Services at the John F. Kennedy Space Center, November 10, 1998
- Roles and Responsibilities of Launch Site Integration Manager, FY 1999
- Parallax Engineering, Inc. Monthly Progress Report on ELV Technical Support, April 1999
- KSC/ELV Denver Resident Office Function, FY 1999
- KSC and JPL Partnership Agreement for Launch Systems Engineering/Future Missions and Advanced Development, April 2, 1999
- KSC/ELV Mission Analysis Branch Roles and Responsibilities, FY 1999
- KSC/ELV Integration Engineering Roles and Responsibilities, FY 1999
- ELV Launch Services Project Status Reports
- ATLAS IIAS/EOS AM-1, Field Operations Plan, November 18, 1997

KSC ELV Launch Service Contracts

- NAS5-30722, Medium Class ELV (MELVS)
- NAS5-32933, Med-Lite ELV
- NAS5-32836,Ultra-Lite ELV
- Small ELV’s, SELVS II,
- NAS3-27262, Intermediate ELV
- NAS3-23440, GOES
- NAS5-98069, GOES, N-Q
- NAS5-31481, Small ELV’s
- Titan II QuickSCAT

SMA/ELV Organization and Program

- Proposed KSC/SMA Reorganization Plan, FY 1999
- KSC/SMA AOA, FY 1999
- AOA Gap Analysis, January 1999
- KSC Process Verification (PV), July 2,1998
- Business Objectives & Agreement (BOA) current
- In-Work BOA Revision
- MOU Range Safety
- Draft MOU for ELV Safety (M/Q/KSC)
- NASA Std 8709.2 SMA Roles and Responsibilities for ELV's, August 1998
- NASA Std 8719.8, ELV and Payload Safety Review Process, June 1998
- In-Work Govt. Surveillance Plan for ELV's
- ISO Process requirements for ELV/SMA
- Applicable KMI's
- Applicable Mil-Stds
- Mil Q-9858a (Quality)
- Mil I-45208 (Inspection)
- etc.
- Failure Investigation Reports for recent and past ELV mishaps
- (Air Force/Industry/NASA)
- KSC/SMA program surveys and audits of ELV program activity
- KSC Strategic Management Plan (SMA tactical implementation plan)
- NASA ELV Acquisition And Management Policy to BAR Procurement
- Panel, August 4,1999

FUSE

- Pedigree Review, Aerospace Corporation, June 21, 1999
- NASA ELV Readiness Assessment Process, May 7, 1999
- Vehicle Subsystem Turnover Review Presentation Package, Boeing, September 14, 1998
- Vehicle Subsystem Turnover Review Presentation Package, Boeing, October 14, 1998
- Vehicle Subsystem Turnover Review Presentation Package, Boeing, February 5, 1999
- Hardware Assessment Review RS-27 Engine System, S/N 2062
- April 21, 1997
- Post Production Hardware Review Presentation, Boeing, January 5, 1999
- Post Production Hardware Review Presentation, Boeing, November 6, 1998
- First Stage S/N 20079 Anomaly Status Report, NASA, July 10, 1998
- Launch Vehicle Readiness Review, KSC, April 30, 1999
- Flight Readiness Review, June 6, 1999
- Pre Vehicle-on-Stand Review, April 21, 1999

Terra

- Terra Independent Assessment Team, June 15, 1999
- Minutes/Action from the terra Launch Services Independent Review
- Meeting, June 15, 1999

QuikSCAT

- Missile System Prelaunch Safety Package, Revision B, Ball Aerospace Corporation, March 1999
- System Safety Program Plan, Ball Aerospace Corporation, June 1998
- Briefing, Technical Oversight Performed for the Titan II/ QuikSCAT Mission, NASA, June 4, 1999
- QuickSCAT Mission Readiness Review, NASA April 26,1999
- T-II Mission Assurance Comparison, Aerospace Corporation, June 8, 1999
- Draft QuikSCAT Red Book
- NASA Letter of Contract Administration Delegation, Special Instructions For
- Quality Assurance, January 23, 1998
- Preliminary Verification of Titan IIG-7/QuicSCAT Launch Readiness, Aerospace Corporation, June 17, 1999
- Aerospace Launch Verification TIIG-7,June 11, 1999
- Aerospace List of QuikSCAT Support Tasks, FY 1999
- Lockheed Martin Astronautics, Denver, CO. MOA and Support Plan for DCMC, FY 1999
- Titan II G-7 Astronautics Presidents Launch Readiness Review June 8, 1999
- MOU Between NASA and the U. S. Air Force on Titan II Launch Support for the QuickSCAT Mission
- QuickSCAT Launch Management Coordination Meeting at VAFB, FY 1999

Other References

- Code Q Briefing May 7, 1999
- Code M Briefing May 7, 1999
- Kickoff Letter
- Broad Area Review Draft Charter, USAF Space Command, May 5, 1999

Appendix C
Discovery Telecons and Onsite Interviews

Discovery Telecons

Date	Individual	Organization/Subject Area
6/29/99	Ray Lugo	Overview Briefing of ELV Program
6/30/99	Bruce Reid	Electrical
7/1/99	Darren Bedell	Mission Integration
7/2/99	Mark Reuther Wendy Johnson	Spacecraft Integration
7/5/99	Jim Robinson	Engineering Integration
7/6/99	Darren Bedell	Mission Integration and Customer Division Chief
7/6/99	Tricia Fertig	Mechanical
7/7/99	Chuck Dovale	Launch Operations
7/8/99	Mike Hallet Mark Kramer Kevin Sheahan	Production Engineering

Onsite Interviews

7/12/99	Mike Carney	Independent Analysis
7/12/99	Dan Johnson	Tour Pad 36A
7/12/99	Bruce Reid	DEMCO and Hanger AE
7/12/99	Bob Hammond	Difference between FA and QA, Authority and Resources to Assess Contractor Implementation

7/12/99	Glenn Otto	Flight Assurance
7/13/99	Frank Stone Wendy Johnson Craig Whittaker Pat Hanan	MIT for Galex
7/13/99	Mike Stelzer G. Haddad Ken Carr Roger Sarkovices Darren Bedell	MIT for GOES-L
7/13/99	Mike Benik James Wood	ERB Process
7/14/99	Denise Pham	Atlas Electrical Engineering
7/14/99	Bill Fletcher	Surveillance Planning

QuikSCAT

6/99	Chris Fairey	Director KSC/SMA
6/99	Ann Montgomery	Dep. Director KSC/SMA
6/99	Glenn Otto	KSC/SMA Flight Assurance Manager
6/99	Bob Hammond	KSC/SMA/ELV QA Manager
6/99	Robyn Witter	KSC/SMA/ELV Flight Assurance
6/99	Doug Newsome	NASA Safety /VAFB
6/99	Ray Lugo	Launch Director NASA KSC/ELV

6/99	Mike Benik	Chief, Engineering and Analysis Division NASA KSC/ELV
6/99	Mark Kramer	ELV Eng. Resident Off. At LMA Denver
6/99	Capt. David Painter	U.S. Air Force Titan II SPO
6/99	John Shaughnessy	Aerospace Corporation
6/99	Robert Nicol	LMA Project Manager Titan II
6/99	Mike Kelly	GSFC Code 300
6/99	Jim Ralston	GSFC Code 300 DCMC Representative at Ball Aerospace
6/99	Jim Graf	QuikSCAT Program Manager JPL
6/99	Joe Plamondon	QuikSCAT payload Flight Assurance Manager JPL

FUSE

6/99	Glenn Otto	KSC/SMA Flight Assurance Manager
6/99	Bob Hammond	KSC/SMA/ELV QA Manager
6/99	Robyn Witter	KSC/SMA/ELV Flight Assurance
6/99	Randy Stone	SMA/ELV/FA Mang. Huntington Beach
6/99	Ray Lugo	Launch Director NASA KSC/ELV
6/99	James Wood	NASA/ELV Chief Eng.

Additional Interviews and Telecons

Individual	Organization	Program Affiliation
Gary Bollenbacher	GRC	ELV IV&V Software
Bruce Clark	GSFC	Launch Services Project Manager
Tim Best	GRC	Former GRC ELV Flight Assurance Manager
Janos Barsody	GRC	Former ELV Mission Manager
Jack Wolfe	KSC	ELV Resources
John Schaffer	HQ/MV	ELV Requirements
Al Sofge	HQ/MV	ELV Requirements Office
Celeste Dalton	HQ/HK	Procurement Policy
Rosemary Brunner	GSFC	OLS Resources
Charles Vanek	GSFC	SMA Director
Paul Goozh	HQ	Former NASA ELV Program Manager
Patrick Martin	DOT/FAA	Office of Commercial Space Transportation
Gary Olson	KSC	NASA KSC ELV QA Manager (retired)

Appendix D
Telecon and Onsite Interview Question Outline

- What is your current staffing level?
- Are you comfortable with your current staffing level?
- What level of contractor support exists?
- Are there documented processes defining engineering support activities for each launch? (KDP's)
- What data or metrics do you track concerning contractor performance?
- What are the cardinal requirements documents you work from?
- How many launches do you expect to support in the next 12 months?
- What is your involvement activity in the preparation of RFP's, MOA's and other procurement instruments?
- Do you verify contractor implementation of assurance processes contained in the governing assurance document used in source selection and imposed on the contract (SEP, Quality Plan, PAIP, etc.), for example:

    - workmanship
    - configuration control
    - parts and fasteners
    - worker certification

- To what extent is your group involved in verifying implementation of the contractor ISO 9001 Quality Management Plan?
- Describe the division of 8610.23 tasks within the SMA/FA organization?
- Describe 8610.23 "Approval" activities. What is approved? Who approves it?
- Describe 8610.23 "Insight" activities. What is your definition of insight?
- What engineering and SMA support do you receive from GSFC?
- What engineering and SMA support do you receive from GRC?
- Can you recommend changes which could improve the overall NASA ELV program management and help improve safety, manage risk and increase the likelihood of mission success?
- Do you conduct formal risk assessments and risk analysis?
- What is your role in approving or participating in risk management decisions affecting:

    - NASA Mission-peculiar hardware?
    - NASA Mission-peculiar software?
    - Core Vehicle hardware?
    - Core vehicle software?
    - GSE
    - Propellant

- Do you conduct independent analysis to verify contractor analysis?
- What is included in your review(s) of contractor analyses?
- What do you do differently for special cases issues (IFAs, failures, incidents?)
- What is your involvement with routine core vehicle engineering issues?
- What is your involvement with mission-peculiar hardware/software?
- Describe the interface between design engineering and manufacturing engineering?
- Describe the interactions and interfaces with the following organizations, as appropriate:

  - KSC/ELV internal organization (PM and Launch Services)
  - KSC/SMA
  - In-Plant Engineering Representatives
  - DLA/DPRO
  - In-Plant Flight Assurance Managers
  - HQ/Code M
  - HQ/Code Q
  - USAF Assurance Managers
  - VAFB
  - 45th Space Wing